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Assessment of Eastern Georges Bank Atlantic Cod for 2007

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ABSTRACT

Combined Canada/USA catches, which averaged 17,500 mt between 1978 and 1992, peaked at 26,460 mt in 1982, declined to 1,804 mt in 1995, fluctuated around 3,000 mt until 2003 and subsequently declined again. Catches in 2006 were 1,615 mt, including 441 mt of discards. Canadian catches increased to 1,450 mt in 2006 from 861 mt in 2005. USA catches declined to 166 mt in 2006 from 277 mt in 2005.

Adult population biomass declined substantially from 43,800 mt in 1990 to 8,500 mt in 1995, the lowest observed. The biomass subsequently increased to 19,600 mt in 2001, declined to 13,400 mt in 2005 but increased again to 20,200 mt at the beginning of 2007. Recruitment at age 1 of the 2003 year class, at 7.7 million, is the first above average (6.3 million for 1978-2006) cohort since the 1990 year class. The 2002 and 2004 year classes, at about 1 million each, are the lowest on record. The initial estimate of the 2005 year class is below average, at 2.1 million. Fishing mortality for ages 4-6 increased sharply between 1989 and 1993 from 0.5 to 1.0. In 1995, fishing mortality declined substantially to F=0.19, due to restrictive management measures. Fishing mortality subsequently fluctuated between 0.18 and 0.50 until 2005 when it declined to 0.10 and was 0.15 in 2006, below F_{ref}=0.18.

Assuming a 2007 catch equal to the 1,900 mt total quota, a combined Canada/USA catch of about 2,700 mt in 2008 would result in a neutral risk (50%) that the fishing mortality rate in 2008 will exceed F_{ref} and a neutral risk (50%) that the 2009 adult biomass will be lower than the 2008 adult biomass. A 20% biomass increase is unlikely even with no catch, but a catch of 700 mt results in a neutral risk that biomass would fail to increase by 10%.

RÉSUMÉ

Les prises combinées du Canada et des États-Unis, qui étaient en moyenne d'environ 17 500 tm entre 1978 et 1992, ont culminé à 26 460 tm en 1982 et sont tombées à 1 804 tm en 1995, puis elles ont fluctué autour de 3 000 tm jusqu'en 2003 et ont décliné à nouveau par la suite. En 2006, les prises étaient de 1 615 tm, y compris 441 tm de rejets. Les prises canadiennes ont augmenté, passant de 861 tm en 2005 à 1 450 tm en 2006. Les prises américaines ont décliné, passant de 277 tm en 2005 à 166 tm en 2006.

Il y a eu une baisse importante de la biomasse des adultes, qui est passée de 43 800 tm en 1990 à 8 500 tm en 1995, soit le chiffre le plus bas jamais observé. La biomasse a ensuite grimpé à 19 600 tm en 2001, elle est tombée à 13 400 tm en 2005, mais elle s'est accrue à nouveau, passant à 20 200 tm au début de 2007. Le recrutement à l'âge 1 de la classe de 2003, dont l'effectif est de 7,7 millions de poissons, représente la première cohorte supérieure à la moyenne (6,3 millions pour 1978-2006) depuis la classe de 1990. Les classes de 2002 et 2004, qui comptent chacune environ un million de poissons, sont les plus basses jamais observées. L'estimation initiale de la classe de 2005 se situe au-dessous de la moyenne, à 2,1 millions. Le taux de mortalité par pêche parmi les âges 4-6 a connu une hausse marquée entre 1989 et 1993, passant de 0,5 à 1,0. En 1995, la mortalité par pêche est tombée à F = 0,19, en raison de mesures de gestion restrictives. Par la suite, la mortalité par pêche a fluctué entre 0,18 et 0,50 jusqu'en 2005 et elle est ensuite tombée à 0,10 et était de 0,15 en 2006, en dessous du niveau de référence de 0,18.

En se fondant sur des prises hypothétiques égales au quota total de 1 900 tm en 2007, des prises combinées du Canada et des États-Unis d'environ 2 700 tm en 2008 se traduiraient par un risque neutre (50 %) que le taux de mortalité par pêche en 2008 dépasse le niveau de référence, et par un risque neutre (50 %) que la biomasse des adultes de 2009 soit plus faible que la biomasse des adultes de 2008. Une augmentation de 20 % de la biomasse est peu probable même sans prises, mais des prises de 700 tm en 2007 se traduiraient par un risque neutre que la biomasse ne puisse connaître une augmentation de 10 %.

Introduction

For the purpose of developing a sharing proposal and consistent management by Canada and the USA, agreement was reached that the transboundary management unit for Atlantic cod would be limited to the eastern portion of Georges Bank (DFO Statistical Unit Areas 5Zj and 5Zm; USA Statistical Areas 551, 552, 561 and 562; Figure 1; DFO 2002). This assessment applies the consensus benchmark formulation employed by Gavaris et al (2006) using Canadian and USA fishery information updated to 2006, Fisheries and Oceans Canada (DFO) survey updated to 2007, National Marine Fisheries Services (NMFS) spring survey updated to 2007 and NMFS fall survey updated to 2006.

Fishery

Commercial Fishery Catches

Combined Canada/USA catches, which averaged 17,500 mt between 1978 and 1992, peaked at 26,460 mt in 1982, declined to 1,804 mt in 1995, fluctuated around 3,000 mt until 2003 and subsequently declined again. Catches in 2006 were 1,615 mt, including 441 mt of discards (Table 1, Figure 2). In this report, catches include discards in all years where discard estimates were available and for both the USA and Canada.

Canadian catches peaked at 17,895 mt in 1982 and declined from 14,435 mt in 1990 to 1,138 mt in 1995 (Table 1, Figure 2). Since 1995, with reduction in cod quotas, the fishery has reduced targeting for cod through changes in fishing practices. From 1995-2005 catches fluctuated between 861 mt and 3,404 mt. Canadian catches increased to 1,450 mt in 2006 from 861 mt in 2005. Landings in 2006 were 1,096 mt, taken primarily between June and December by otter trawl and longline (Table 2). All 2006 landings were subject to dockside monitoring. As well, at sea observers monitored about 25% (by weight) of 2006 landings. Van Eeckhaute and Gavaris (2004) estimated discards of cod by the groundfish fishery in 1997-1999 at 428 mt, 273 mt and 253 mt respectively and Gavaris et al (2006) estimated discards at 144 mt in 2005. Estimated discards of cod by the groundfish fishery in 2006 were 237 mt (Gavaris, Van Eeckhaute and Clark 2007). Since 1996 the Canadian scallop fishery has not been permitted to land cod. Landings until 1995 include those catches reported by the scallop fishery. Estimated discards of cod by the Canadian scallop fishery ranged up to 200 mt annually since 1978 (Van Eeckhaute et al 2005), and were 117 mt in 2006 (Gavaris, Robert and Van Eeckhaute 2007).

USA catches increased from 5,502 mt in 1978 to 10,551 mt in 1984, then declined and fluctuated around 6,000 mt during 1985-1993 (Table 1, Figure 2). Since December 1994, a year-round closure of Area II (Figure 1) has been in effect, with the exception of a Special Access Program in 2004. Minimum mesh size limits were increased in 1994, 1999 and in 2002. Limits on sea days, as well as trip limits, have also been implemented. USA catches during 1994-2000 ranged between 558 mt to 1,234 mt and increased to 1,900 mt in 2003. Quotas were introduced in May 2004. USA catches declined to 166 mt in 2006 from 277 mt in 2005. Most of the 2006 catch was taken in the second quarter. Of the 79 mt landed, 90% was caught by otter trawl gear, 6% by gillnet and 5% by longline. Discard to kept ratios were estimated quarterly from observed trips in the Northeast Fisheries Science Center Observer Data Base System (OBDBS) and applied to quarterly landings to estimate annual discards. Estimated discards of cod in the groundfish fishery for 1989-2004 were generally less than 100 mt annually, increased to 153 mt in 2005, and declined to 87 mt in

2006. Otter trawl gear accounted for 96% of the discards with longline and scallop gear accounting for the remainder.

Size and Age Composition

The size and age compositions of the 2006 landings by the Canadian groundfish fishery were derived from port and at-sea samples from all principal gears and seasons (Table 3, Figure 3). Comparison of port and at-sea length frequencies did not indicate any discrepancies (Figure 4), therefore at-sea samples were pooled with port samples to derive catch at length and age. Landings peaked at 58 cm (22 in) for bottom trawlers (Figure 5) while longliners displayed a broad peak between 58 cm (23 in) and 80 cm (32 in). Gill-netters caught fewer cod but these fish were larger, peaking at 80 cm (32 in). Cod discards from the 2005 Canadian groundfish fishery were assumed to have the same size composition as bottom trawl landings since these were not considered the result of high-grade culling. The size composition of cod discards from the 2006 Canadian scallop fishery was derived from at-sea sampling. Cod discards from the scallop fishery peaked at 49 cm (19 in) and tend to be smaller than cod caught by the groundfish fishery. The size composition of combined landings and combined discards both peak at 55 cm (22 in) (Figure 6).

Samples from the 2006 USA fishery on eastern Georges Bank were insufficient to characterize the size composition of the landings (Table 3). Due to the potential for differences in selectivity of gear between USA and Canadian fleets, length samples from the USA fishery on western Georges Bank were included to supplement those from eastern Georges Bank. Landings peaked at 65 cm (26 in) (Figure 7). Discards-at-length for the 2006 USA otter trawl fishery were estimated from observed trips in the OBDBS. The cod discards peaked at 53 cm (21 in) (Figure 7) and tended to be smaller than landed cod. Commercial fishery and NMFS survey age-length keys were applied to discards-at-length to derive discards-at-age. Annual length-weight relationships, derived from OBDBS samples, were used in the computation of numbers discarded from weight discarded.

The percent catch composition, combined landings and discards, for Canada and USA were similar (Figure 8). Age composition was obtained by applying quarterly fishery age-length keys to the size composition. Comparisons indicated good agreement between DFO and NMFS age readers (Sutherland et al 2007). The age-length key from 2006 DFO survey, conducted in February, was used to augment the first quarter key. USA fishery age samples from eastern Georges Bank were limited and were supplemented with Canadian fishery age samples. The combined Canada/USA 2006 fishery age composition was dominated by the 2003 year class at age 3 (40% by number) but the 2001 year class at age 5 continued to make an important contribution (30% by number) (Figure 9). The USA groundfish fishery cod discard catch at age for 1989-2006 and the Canadian groundfish fishery and scallop fishery cod discard catch at age for 1978-2006 were included in the assessment. The catch at age for 1978-2005 was updated with the 2006 catch at age. The contribution of fish older than age 7 to the catch continues to be small (Table 4, Figure 10).

Fishery weights at age show a declining trend starting in the early 1990s, particularly at older ages (Table 5, Figure 11). The rate of decline was not as pronounced in the most recent years. However, 2006 fishery weights at age remained near the lowest observed since 1978 for all ages.

Abundance Indices

Surveys

Surveys of Georges Bank have been conducted by DFO each year (February) since 1986 and by NMFS each autumn (October) since 1963 and each spring (April) since 1968. All surveys use a stratified random design (Figures 12 and 13). Most of the DFO surveys have been conducted by the *Alfred Needler*. A sister ship, the *Wilfred Templeman*, conducted the survey for two years and another vessel, the *Teleost*, conducted 6 of the sets in 2006. No conversion factors were applied. For the NMFS surveys, two vessels have been employed and there was a change in the trawl door in 1985. Vessel and door type conversion factors (Table 6), derived experimentally from comparative fishing, have been applied to the survey results to make the series consistent (Forrester et al 1997). Additionally, two different trawl nets have been used on the NMFS spring survey, a modified Yankee 41 during 1973-81 and a Yankee 36 in other years, but no conversion factors are available for cod.

The spatial distribution of ages 3 and older cod caught during the 2007 DFO survey was unlike that observed from surveys over the previous decade (Figure 14). In February 2007 cod were distributed widely throughout the Canadian portion of eastern Georges Bank whereas in previous years, the highest densities were observed on the northern part of the bank at depths less than 100 m. Total catch in numbers in the 2007 DFO survey declined slightly from 2006 with strong representation by the 2003 year class at age 4 (Table 7). The 2007 NMFS spring survey distribution of cod also showed a fairly dispersed pattern relative to the previous decade, but extending further west into the USA portion of eastern Georges Bank (Fig 15). Total catch in numbers for the 2007 NMFS spring survey increased slightly between 2006 and 2007, largely supported by the 2003 year class at age 4 (Table 8). The high index observed in 2004 appears to be a year effect. The 2006 NMFS autumn catch distribution was primarily along the Northern Edge (Fig. 16) and similar to the pattern observed during the previous decade. Total catch in numbers in the 2006 NEFSC autumn survey increased from 2005 with the 2003 year class at age 3 contributing substantially (Table 9).

Survey abundance at age (Tables 7-9, Figure 17) shows poor recruitment since the 1990 year class. The 2003 year class appears good but it is not exceptional. There is a weak indication of increasing abundance at older ages in recent years.

Weights at age derived from the DFO survey display a declining trend since the early 1990s (Table 10, Figure 18), the trend being pronounced at older ages. However, in comparison to the fishery weights at age, the decline appeared more severe between 2000 and 2006, but in 2007 the weight at age increased at most ages. Cod condition, measured as average weight at length at 3 representative length groupings, derived from the DFO survey does not show any notable trends (Figure 19).

Harvest Strategy

The Transboundary Management Guidance Committee has adopted a strategy to maintain a low to neutral risk of exceeding the fishing mortality limit reference, $F_{ref} = 0.18$. When stock conditions are poor, fishing mortality rates should be further reduced to promote rebuilding.

Estimation and Diagnostics

The state of the resource was based on results from an age structured analytical assessment (VPA) that used fishery catch statistics and sampling for size and age composition of the catch for 1978 to 2006 (including discards). The VPA was calibrated to trends in abundance from three bottom trawl survey series; NMFS spring, NMFS fall and DFO.

A consensus model formulation was established during the benchmark assessment review (NEFSC 2002). The adaptive framework, ADAPT, (Gavaris 1988) was used to implement the benchmark formulation for calibrating the virtual population analysis with the research survey data. Computational formulae used in ADAPT are described by Rivard and Gavaris (2003a). The data used in the model were:

$C_{a,t}$ =catch at age for ages a = 1 to 10 and time t = 1978 to 2006, where t represents the year during which the catch was taken
$I_{1,a,t}$ = DFO survey for ages a = 2 to 7 and time t = 1986.16, 1987.16… 2006.16, 2007.00
$I_{2,a,t}$ = NMFS spring survey (Yankee 41) for ages a = 1 to 8 and time t = 1978.29, 1979.29, 1980.29, 1981.29
$I_{3,a,t}$ = NMFS spring survey (Yankee 36), for ages a = 1 to 8 and time t = 1982.29, 1983.29… 2006.29, 2007.00
$I_{4,a,t}$ = NMFS autumn survey, ages a = 1 to 5 and time t = 1978.69, 1979.69… 2006.69.

The population was calculated to the beginning of 2007.00, therefore the DFO and NMFS spring survey indices for 2006 were designated as occurring at the beginning of the year, i.e. 2006.00. The benchmark formulation assumes that observation errors for the catch at age data were negligible. Observation errors for the abundance indices at age are assumed to be independent and identically distributed after taking natural logarithms of the values. Zero observations for abundance indices were treated as missing data as the logarithm of zero is not defined. The annual natural mortality rate, M, was assumed constant and equal to 0.2 for all ages in all years. Fishing mortality on age 10 for 1978 to 1997 was assumed to be equal to the population number weighted average fishing mortality on ages 8 and 9.

Estimation was based on minimization of the objective function:

$\sum_{s,a,t}\left(lnI_{s,a,t} - \left(\hat{\kappa}_{s,a} + v_{a,t}\right)\right)^2$, where s indexes survey.

The estimated model parameters were:
$v_{a,t} = lnN_{a,t} = ln$ population abundance for a = 2 to 11 at time t = 2007 and for a = 11 at time t = 1999 to 2006
$\kappa_{1,a} = ln$ DFO survey catchability for a = 2 to 7
$\kappa_{2,a} = ln$ NMFS spring survey (Yankee 41) catchability for ages a = 1 to 8
$\kappa_{3,a} = ln$ NMFS spring survey (Yankee 36) catchability for ages a = 1 to 8
$\kappa_{4,a} = ln$ NMFS autumn survey catchability for ages a = 1 to 5.

Statistical properties of estimators were determined using conditional non-parametric bootstrapping of model residuals (Efron and Tibshirani 1993, Rivard and Gavaris 2003a). The population abundance estimate at age 2 at the beginning of 2007 exhibited the largest relative bias of 12%, while that for other ages/times ranged between 3% and 10%. The relative error ranged between 30% and 60% (Table 11). Survey catchability at age for the

DFO and NMFS spring (Yankee 36) surveys progressively increased until about age 4 or 5 and then fluctuated. Survey catchability at age for the NMFS autumn survey is highest at age 3. While trends in the surveys are generally consistent, the survey indices exhibit high variability and the average magnitude of residuals is large. Some patterns in the residuals suggest year effects (Figures 20-24). The overall fit of model estimated biomass and recruitment to the DFO, NMFS spring and NMFS fall surveys was good but the estimated biomass prior to the mid 1990s had a tendency to be higher than the surveys indicated (Figures 25-27).

Retrospective analyses were used to detect any patterns to consistently overestimate or underestimate fishing mortality, biomass and recruitment relative to the terminal year estimates. The extent of the pattern for this assessment was similar to that seen in the past and was not of concern (Figures 28-29), though there was a general tendency to initially underestimate some recent year-classes as recruits at age 1 (Figure 30).

State of Resource

Recruitment at age 1 of the 2003 year class, at 7.7 million, is the first above average (6.3 million for 1978-2006) cohort since the 1990 year class (Table 12, Figure 31). Prior to the 2003 year class, the 1996 and 1998 year classes, at over 4 million, were the strongest since the 1990 year class. The 2002 and 2004 year classes, at about 1 million each, are the lowest on record. The initial estimate of the 2005 year class is below average, at 2.1 million.

Fishing mortality for ages 4-6 increased sharply between 1989 and 1993 from 0.5 to 1.0 (Table 13, Figure 32). In 1995, fishing mortality declined substantially to F=0.19, due to restrictive management measures. Fishing mortality subsequently fluctuated between 0.18 and 0.50 until 2005 when it declined to 0.10 and was 0.15 (80% Confidence Interval: 0.13 – 0.20) in 2006, below F_{ref}=0.18.

Adult population biomass (ages 3+) declined substantially from 43,800 mt in 1990 to 8,500 mt in 1995, the lowest observed (Table 14, Figure 31). The biomass subsequently increased to 19,600 mt in 2001, declined to 13,400 mt in 2005 but increased again to 20,200 mt at the beginning of 2007 (80% Confidence Interval: 16,000 mt – 24,000 mt). Much of the increase in the late 1990's was the result of growth and survival to ages 5+ of the 1992, 1995 and 1996 year classes. The increase in 2006 was due largely to recruitment of the 2003 year class and the increase in 2007 was due to growth of the 2003 year class. Lower weights-at-age in the population in recent years and the generally poor recruitment have contributed to the lack of sustained rebuilding.

Yield exceeded surplus production during the early 1990s (Figure 33). Surplus production since the mid 1990s has remained considerably lower than that prior to 1990. Growth of ages 2 to 10 has typically accounted for the greatest percentage of the production (Figure 34). Occasionally, a strong incoming year-class at age 2 makes a greater contribution to production. While there has been a tendency for greater chance of good recruitment when biomass exceeded 25,000 mt (Figure 35), there is high recruitment variability at any given biomass. Since the early 1990s, biomass has remained below 25,000 mt and recruitment has been poor.

Productivity

Age structure, fish growth, recruits per spawner, and spatial distribution reflect changes in the productive potential. In both absolute numbers and percent composition, the population age structure displays a higher abundance at older age groups compared to the mid 1990s. However, the abundance for older ages may not be well determined. Average weight at length, used to reflect condition, has been stable, but declines in weight at age have hampered biomass rebuilding. The recruit per adult biomass ratio has been generally lower than that seen prior to 1990, with the exception of occasional year classes like the 2003 year class (Figure 36). Spatial distribution patterns observed during the most recent bottom trawl surveys showed that adult cod were more widespread than the average over the previous decade. Resource productivity is currently poor due to low weight at age and generally low recruit per spawner ratio.

Outlook

This outlook is provided in terms of consequences with respect to the harvest reference points for alternative catch quotas in 2008 (Rivard and Gavaris 2003b). Uncertainty about standing stock generates uncertainty in forecast results which is expressed here as the risk of exceeding F_{ref} =0.18. The risk calculations assist in evaluating the consequences of alternative catch quotas by providing a general measure of the uncertainties. However, they are dependent on the data and model assumptions and do not include uncertainty due to variations in weight at age, partial recruitment to the fishery, natural mortality, systematic errors in data reporting or the possibility that the model may not reflect stock dynamics closely enough.

For projections, the 2004-2006 average values were assumed for the fishery weight at age and partial recruitment pattern in 2007-2008 and the 2005-2007 survey average values were assumed for beginning of year population weight at age in 2008-2009 (Table 15). The recent three year averages were used to account for the trend in weight at age and associated impact on fishery partial recruitment. Assuming a 2007 catch equal to the 1,900 mt total quota, a combined Canada/USA catch of about 2,700 mt in 2008 would result in a neutral risk (50%) that the fishing mortality rate in 2008 will exceed F_{ref} and a neutral risk (50%) that the 2009 adult biomass will be lower than the 2008 adult biomass (Figure 37). A 20% biomass increase is unlikely even with no catch, but a catch of 700 mt results in a neutral risk (50%) that biomass would fail to increase by 10%. A status quo catch of about 1,900 mt in 2008 would result in a low risk (less than 25%) that the adult biomass would decrease from 2008 to 2009 and a high chance of maintaining the fishing mortality below F_{ref}=0.18.

The 2003 year class is projected to contribute over 50% of the fishery catch biomass in 2007 and 2008 (Table 16). With below average 2004 and 2005 year classes, exploitation below F_{ref} would maintain biomass at higher levels in the near future, increasing chances of better recruitment.

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Table 1. Catches (mt) of cod from eastern Georges Bank during 1978-2006.

	Canada			USA			Total
Year	Landings	Discards	Total	Landings	Discards	Total	
1978	8778	98	8876	5502		5502	14378
1979	5978	103	6081	6408		6408	12489
1980	8063	83	8146	6418		6418	14564
1981	8499	98	8597	8094		8094	16691
1982	17824	71	17895	8565		8565	26460
1983	12130	65	12195	8572		8572	20767
1984	5763	68	5831	10551		10551	16382
1985	10443	103	10546	6641		6641	17187
1986	8504	51	8555	5696		5696	14251
1987	11844	76	11920	4792		4792	16712
1988	12741	83	12824	7645		7645	20469
1989	7895	76	7971	6182	158	6340	14311
1990	14364	70	14435	6378	61	6439	20873
1991	13462	65	13526	6777	144	6921	20448
1992	11673	71	11744	5080	129	5209	16953
1993	8524	63	8586	4019	66	4085	12671
1994	5278	63	5340	1228	6	1234	6575
1995	1100	38	1138	665	1	666	1804
1996	1926	56	1982	773	2	775	2757
1997	2919	486	3404	557	1	558	3963
1998	1907	365	2272	795	2	797	3069
1999	1818	338	2156	1150	7	1157	3314
2000	1572	69	1641	661	11	672	2313
2001	2143	143	2285	1361	83	1444	3730
2002	1279	94	1373	1379	37	1416	2789
2003	1325	200	1525	1813	87	1900	3425
2004	1111	145	1257	980	74	1053	2310
2005	630	231	861	124	153	277	1139
2006	1096	354	1450	79	87	166	1615
Minimum	630	38	861	79	1	166	1139
Maximum	17824	486	17895	10551	158	10551	26460
Average	6572	132	6704	4099	62	4138	10842

Table 2. Nominal landings (mt) of cod from eastern Georges Bank by gear and month for Canada during 1997-2006.

Year	Gear	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1997	Gillnet						133	133	107	51	47			470
	Longline						177	432	385	255	132	15	21	1416
	Mobile						360	166	210	135	56	52	53	1033
	Total						**670**	**731**	**703**	**440**	**235**	**67**	**74**	**2919**
1998	Gillnet						76	90	63	25	46			300
	Longline						74	345	221	197	87	21	18	963
	Mobile						178	71	138	95	99	39	27	645
	Total					**0**	**328**	**505**	**422**	**316**	**232**	**60**	**45**	**1907**
1999	Gillnet						59	100	48	15	36	7	6	270
	Longline						95	288	244	152	107	27	17	929
	Mobile	3					226	156	47	72	59	38	19	619
	Total	**3**					**379**	**544**	**339**	**239**	**201**	**71**	**42**	**1818**
2000	Gillnet						55	76	28	24	41	9	4	238
	Longline						41	191	177	222	138	15	16	800
	Mobile	0					102	140	82	73	70	38	30	535
	Total	**0**					**197**	**407**	**287**	**318**	**248**	**63**	**51**	**1572**
2001	Gillnet						37	75	48	60	43	21		284
	Longline						62	212	273	282	229	62	16	1137
	Mobile						160	84	58	104	134	111	72	722
	Total						**259**	**371**	**379**	**446**	**406**	**193**	**89**	**2143**
2002	Gillnet						3	45	51	23	1	9	7	140
	Longline						2	151	199	162	127	31	30	700
	Mobile						38	87	34	78	62	55	86	439
	Total						**43**	**283**	**283**	**263**	**190**	**95**	**123**	**1279**
2003	Gillnet						6	30	31	24	3	14	1	110
	Longline						22	181	238	138	121	28	14	742
	Mobile						88	84	54	64	69	70	45	474
	Total						**116**	**295**	**324**	**227**	**193**	**112**	**59**	**1325**
2004	Gillnet						4	2	14	21	0	11	0	52
	Longline						6	85	231	168	88	96	14	688
	Mobile						78	82	50	47	56	42	16	371
	Total						**88**	**169**	**294**	**236**	**144**	**149**	**30**	**1111**
2005	Gillnet	0	0			0	11	18	0	6	0	0	0	36
	Longline	1	0			0	9	44	101	71	52	29	4	311
	Mobile	12	22			3	50	49	31	27	28	31	30	283
	Total	**13**	**22**			**3**	**70**	**111**	**133**	**105**	**80**	**60**	**34**	**630**
2006	Gillnet						0	27	15					43
	Longline	3					10	135	180	139	81	34	14	595
	Mobile	42	16				93	73	78	58	36	25	38	458
	Total	**45**	**16**	**0**	**0**	**0**	**104**	**235**	**273**	**197**	**117**	**59**	**52**	**1096**

Table 3. Commercial landings length and age samples from 1978-2006 for eastern Georges Bank Canadian and USA cod fisheries. At-sea observer samples are included in Canadian length samples since 1994 (each trip counted as one sample). Canadian fishery age samples for the first quarter of 2005-2006 were supplemented with DFO survey age samples. USA age samples for 1996-2004 were supplemented with Canadian age samples. (number after supplementing shown in brackets)

	USA			Canada		
Year	Samples	Lengths	Ages	Samples	Lengths	Ages
1978	29	2047	385	29	7684	1308
1979	21	1833	402	13	3991	656
1980	16	1258	286	10	2784	536
1981	21	1615	456	17	4147	842
1982	45	4111	778	17	4756	858
1983	40	3775	903	15	3822	604
1984	44	3891	1130	7	1889	385
1985	23	2076	597	18	7644	1062
1986	27	2145	644	19	5745	888
1987	23	1865	525	33	9477	1288
1988	37	3229	797	43	11709	1984
1989	19	1572	251	32	8716	1561
1990	28	1989	287	40	9901	2012
1991	23	1894	397	45	10873	1782
1992	25	2048	445	48	10878	1906
1993	29	2215	440	51	12158	2146
1994	13	1323	260	104	25845	1268
1995	-	-	-	36	11598	548
1996	3	284[1]	74 (953)	129	26663	879
1997	80	6638[1]	55 (1299)	118	31882	1244
1998	82	7076[1]	46 (1766)	139	26549	1720
1999	70	6045[1]	250 (1168)	84	24954	918
2000	156	12219[1]	41 (1551)	107	20782	1436
2001	108	8389[1]	351 (2423)	108	18190	1509
2002	86	6306[1]	378 (1642)	91	18974	1264
2003	47	2785[1]	385 (1569)	94	20199	1070
2004	31	1872[1]	439 (1481)	127	17859	1370
2005	58	2160[1]	249(1511)	136	21942	786(1483)
2006	34	2156[1]	129(1651)	258	43259	807(1455)

[1] Includes length samples from western Georges Bank.

Table 4. Annual catch at age numbers (thousands) for eastern Georges Bank cod.

Year	Age Group										
	1	2	3	4	5	6	7	8	9	10	1+
1978	2.0	121.0	3588.0	1076.0	307.0	110.0	83.0	21.0	11.6	3.6	5327
1979	10.2	827.6	405.7	1803.7	554.1	151.5	22.4	45.8	3.8	3.1	3829
1980	1.0	994.3	1506.1	267.0	922.8	347.6	109.8	20.1	33.6	5.4	4212
1981	19.2	609.0	1457.3	1261.3	156.5	600.9	170.7	65.6	36.4	18.6	4396
1982	6.0	2692.7	1692.7	1434.7	1070.2	189.8	346.4	157.6	37.2	12.2	7665
1983	40.1	1322.4	3424.7	1477.8	467.2	283.7	31.1	71.2	38.9	5.9	7173
1984	10.1	270.6	916.5	1354.2	514.1	291.8	231.4	31.2	72.8	26.6	3744
1985	12.1	2804.8	1226.6	633.9	945.3	225.0	96.4	100.5	14.4	26.9	6095
1986	28.2	328.5	2204.8	516.9	306.3	403.1	58.4	39.3	25.9	3.6	3925
1987	14.0	3665.8	864.9	1098.9	144.0	121.0	167.0	37.0	23.6	7.6	6147
1988	9.9	317.3	3621.9	640.5	853.7	142.8	101.1	141.8	40.5	19.4	5906
1989	48.8	820.1	667.0	1827.6	191.8	311.7	55.6	24.8	50.9	11.7	4021
1990	9.0	719.5	3215.2	965.9	1199.1	116.4	122.3	10.0	14.3	22.6	6403
1991	33.3	724.1	802.4	1944.5	953.3	790.4	93.0	56.0	17.8	7.1	5434
1992	96.9	2456.9	1252.0	432.1	906.9	249.8	232.8	25.0	26.8	2.4	5686
1993	7.6	458.9	1986.2	812.3	216.1	333.7	110.6	93.6	23.2	17.4	4062
1994	2.9	187.5	488.5	753.0	246.5	40.7	58.8	26.0	20.3	1.1	1826
1995	2.0	56.5	235.2	120.1	89.1	14.4	4.2	3.0	1.5	0.0	526
1996	4.4	41.7	238.5	400.3	78.8	49.8	11.8	2.7	1.8	0.1	830
1997	3.0	136.2	213.7	412.0	461.1	111.8	55.7	18.5	3.7	0.7	1417
1998	0.6	103.2	381.1	198.1	201.2	167.0	26.2	14.9	4.7	1.1	1100
1999	3.3	63.0	540.4	364.4	110.1	61.7	52.1	12.1	2.1	4.6	1214
2000	1.8	59.6	115.8	335.9	129.5	34.6	20.2	12.2	1.8	0.3	712
2001	1.9	112.9	471.5	201.2	375.3	98.4	29.3	17.1	5.4	0.5	1314
2002	3.9	16.5	130.5	377.6	98.0	145.7	25.8	7.5	3.8	1.5	811
2003	1.8	31.6	177.9	276.5	393.6	73.0	81.9	15.9	3.1	1.2	1057
2004	2.9	13.7	132.7	152.3	134.0	128.8	32.9	22.1	4.3	0.8	625
2005	2.3	69.4	46.1	173.9	42.2	29.5	30.3	10.0	4.8	1.1	410
2006	5.5	21.2	232.6	72.5	177.6	43.4	16.6	16.4	2.3	1.4	590

Table 5. Average fishery weights at age (kg) of cod from eastern Georges Bank.

Year	Age Group									
	1	2	3	4	5	6	7	8	9	10
1978	0.71	1.31	2.46	3.47	4.34	5.79	7.37	8.49	11.79	13.62
1979	0.89	1.49	2.15	4.21	4.89	7.18	9.18	10.31	11.70	14.06
1980	0.84	1.46	2.47	3.67	5.65	6.68	8.39	9.09	8.43	14.35
1981	0.88	1.50	2.36	3.42	5.21	7.22	8.57	9.89	14.17	13.57
1982	0.77	1.40	2.66	3.83	5.35	6.51	9.36	9.90	12.50	13.68
1983	0.97	1.49	2.38	3.31	4.64	6.39	7.96	10.29	11.23	12.21
1984	1.05	1.64	2.45	3.62	5.08	6.58	8.91	10.10	11.30	13.79
1985	0.91	1.42	2.09	3.89	5.09	6.41	8.10	10.24	11.42	12.72
1986	0.93	1.48	2.45	3.66	5.60	7.19	8.92	9.96	12.69	8.91
1987	0.73	1.48	2.50	4.19	5.81	7.73	8.95	10.01	11.41	13.93
1988	0.79	1.52	2.36	3.51	5.40	6.65	8.78	9.99	11.14	13.17
1989	0.81	1.62	2.27	3.77	5.40	6.69	8.22	10.72	11.67	14.14
1990	0.83	1.56	2.46	3.52	4.89	6.33	8.46	10.65	12.58	14.04
1991	1.11	1.63	2.55	3.42	4.77	5.89	7.41	10.52	9.69	14.52
1992	1.15	1.54	2.46	3.84	4.70	6.16	7.51	9.85	12.06	14.52
1993	0.88	1.57	2.31	3.08	4.50	5.73	7.08	8.88	9.70	10.86
1994	0.91	1.46	2.41	3.83	4.80	7.09	7.86	8.93	9.70	10.37
1995	0.90	1.49	2.51	3.72	5.22	6.52	11.06	10.12	10.38	14.52
1996	1.03	1.54	2.36	3.34	5.24	6.36	6.92	8.46	12.88	10.51
1997	0.98	1.50	2.23	3.34	4.25	5.80	8.05	8.33	11.87	14.52
1998	0.63	1.48	2.37	3.19	4.27	5.83	6.99	8.30	12.68	11.81
1999	0.80	1.55	2.29	3.53	4.16	6.31	6.78	8.04	12.15	13.54
2000	0.87	1.46	2.13	3.08	4.23	4.92	6.20	7.34	8.27	12.97
2001	0.88	1.49	2.33	3.00	4.05	5.12	5.08	8.02	9.22	14.81
2002	0.55	1.42	2.27	3.08	4.30	5.07	6.75	8.28	8.82	8.46
2003	0.26	1.66	2.15	2.67	3.68	4.35	5.67	7.29	7.86	9.02
2004	0.70	1.37	2.03	2.87	3.45	4.57	5.50	7.35	9.03	8.86
2005	0.33	0.99	1.72	2.48	3.60	4.63	5.01	6.84	8.32	9.19
2006	0.18	0.74	1.76	2.35	3.38	4.41	6.22	5.87	7.13	7.43
Min.	0.18	0.74	1.72	2.35	3.38	4.35	5.01	5.87	7.13	7.43
Max.	1.15	1.66	2.66	4.21	5.81	7.73	11.06	10.72	14.17	14.81
Avg.[1]	0.40	1.03	1.84	2.57	3.48	4.53	5.58	6.68	8.16	8.49

[1]for 2004-2006

Table 6. Conversion factors used to adjust for changes in door type and survey vessel for the NMFS surveys.

Year	Door	Spring		Fall	
		Vessel	Conversion	Vessel	Conversion
1978	BMV	Albatross IV	1.56	Delaware II	1.2324
1979	BMV	Albatross IV	1.56	Delaware II	1.2324
1980	BMV	Albatross IV	1.56	Delaware II	1.2324
1981	BMV	Delaware II	1.2324	Delaware II	1.2324
1982	BMV	Delaware II	1.2324	Albatross IV	1.56
1983	BMV	Albatross IV	1.56	Albatross IV	1.56
1984	BMV	Albatross IV	1.56	Albatross IV	1.56
1985	Polyvalent	Albatross IV	1	Albatross IV	1
1986	Polyvalent	Albatross IV	1	Albatross IV	1
1987	Polyvalent	Albatross IV	1	Albatross IV	1
1988	Polyvalent	Albatross IV	1	Albatross IV	1
1989	Polyvalent	Delaware II	0.79	Delaware II	0.79
1990	Polyvalent	Delaware II	0.79	Delaware II	0.79
1991	Polyvalent	Delaware II	0.79	Delaware II	0.79
1992	Polyvalent	Albatross IV	1	Albatross IV	1
1993	Polyvalent	Albatross IV	1	Delaware II	0.79
1994	Polyvalent	Delaware II	0.79	Albatross IV	1
1995	Polyvalent	Albatross IV	1	Albatross IV	1
1996	Polyvalent	Albatross IV	1	Albatross IV	1
1997	Polyvalent	Albatross IV	1	Albatross IV	1
1998	Polyvalent	Albatross IV	1	Albatross IV	1
1999	Polyvalent	Albatross IV	1	Albatross IV	1
2000	Polyvalent	Albatross IV	1	Albatross IV	1
2001	Polyvalent	Albatross IV	1	Albatross IV	1
2002	Polyvalent	Albatross IV	1	Albatross IV	1
2003	Polyvalent	Delaware II	0.79	Delaware II	0.79
2004	Polyvalent	Albatross IV	1	Albatross IV	1
2005	Polyvalent	Albatross IV	1	Albatross IV	1
2006	Polyvalent	Albatross IV	1	Albatross IV	1
2007	Polyvalent	Albatross IV	1		

Table 7. Indices of abundance (numbers/standard tow) of eastern Georges Bank cod from the DFO survey.

	Age Group										
Year	0	1	2	3	4	5	6	7	8	9+	Total
1986	0.00	1.78	8.19	7.41	0.77	1.60	1.03	0.51	0.08	0.00	21.37
1987	0.00	0.12	4.31	1.55	1.81	0.39	0.21	0.44	0.21	0.13	9.18
1988	0.00	0.36	1.08	12.85	1.36	2.02	0.23	0.19	0.43	0.12	18.64
1989	0.00	0.84	5.22	1.84	4.11	0.62	0.80	0.10	0.20	0.39	14.13
1990	0.05	0.25	1.91	8.36	4.70	10.60	1.29	2.63	0.35	1.46	31.60
1991	0.00	2.88	2.45	3.39	3.95	2.12	2.88	0.36	0.60	0.33	18.96
1992	0.00	0.11	4.93	2.94	0.99	1.55	1.09	0.72	0.22	0.15	12.70
1993	0.00	0.07	0.85	4.15	1.50	0.89	1.82	0.66	0.64	0.26	10.84
1994	0.00	0.03	1.51	1.66	3.10	1.15	0.44	0.88	0.20	0.35	9.32
1995	0.00	0.08	0.45	2.99	1.82	1.25	0.45	0.11	0.16	0.14	7.45
1996	0.00	0.22	0.49	4.20	10.44	3.45	2.49	1.07	0.26	0.48	23.09
1997	0.00	0.07	0.90	1.37	3.19	3.04	0.52	0.12	0.08	0.10	9.40
1998	0.00	0.01	1.40	2.00	0.78	0.76	0.57	0.13	0.07	0.05	5.78
1999	0.00	0.01	0.38	3.12	2.63	1.08	0.76	0.46	0.02	0.11	8.57
2000	0.00	0.00	1.02	3.12	11.96	5.19	2.48	1.23	0.76	0.13	25.89
2001	0.00	0.01	0.09	1.93	1.25	3.35	1.55	0.80	0.54	0.70	10.23
2002	0.00	0.00	0.28	1.15	5.05	1.67	3.09	1.10	0.45	0.35	13.15
2003	0.00	0.00	0.02	0.48	1.23	2.09	0.47	0.53	0.17	0.03	5.00
2004	0.00	1.03	0.10	0.59	0.92	1.02	0.85	0.14	0.26	0.08	4.98
2005	0.00	0.06	2.47	3.37	17.21	4.25	1.97	1.79	0.15	0.24	31.50
2006	0.00	0.00	0.10	3.61	1.62	4.28	1.82	0.52	0.52	0.34	12.82
2007	0.00	0.04	0.31	1.32	6.27	0.91	1.57	0.29	0.20	0.14	11.05

Table 8. Indices of abundance (numbers/standard tow) of eastern Georges Bank cod from the NMFS spring survey.

	Age Group										
Year	0	1	2	3	4	5	6	7	8	9+	Total
1970	0.00	0.68	2.14	0.58	1.17	0.14	0.51	0.09	0.00	0.27	5.59
1971	0.00	0.33	1.29	0.91	0.21	0.59	0.22	0.46	0.41	0.29	4.72
1972	0.10	2.85	3.35	4.47	0.71	0.21	0.25	0.11	0.16	0.21	12.41
1973	0.00	1.20	68.33	9.87	11.02	1.02	0.84	0.75	0.00	0.88	93.92
1974	0.00	0.83	10.60	7.27	1.37	3.61	0.65	0.16	0.48	0.26	25.24
1975	0.00	0.00	0.84	5.52	7.84	0.80	1.73	0.14	0.00	0.22	17.11
1976	0.16	3.33	2.14	1.19	0.85	1.46	0.00	0.32	0.07	0.09	9.62
1977	0.00	0.00	4.25	1.33	0.64	0.55	0.60	0.04	0.06	0.00	7.48
1978	0.67	0.34	0.00	5.10	1.11	1.65	0.28	1.42	0.11	0.15	10.82
1979	0.13	0.61	2.40	0.22	2.58	0.98	0.32	0.16	0.24	0.00	7.64
1980	0.00	0.02	4.33	4.17	0.32	3.81	0.79	0.15	0.09	0.15	13.84
1981	0.53	3.64	2.44	3.74	2.04	0.08	0.84	0.37	0.11	0.00	13.78
1982	0.08	0.82	11.98	24.56	22.85	16.97	0.00	5.57	1.79	0.22	84.83
1983	0.00	0.70	3.64	6.82	1.41	1.10	0.57	0.19	0.18	0.19	14.79
1984	0.00	0.20	0.22	0.66	0.93	0.18	0.35	0.14	0.04	0.20	2.92
1985	0.10	0.07	3.67	1.14	1.91	2.74	0.59	0.39	0.38	0.46	11.46
1986	0.17	1.12	0.61	2.04	0.54	0.77	0.97	0.04	0.20	0.26	6.71
1987	0.00	0.00	2.15	0.45	1.02	0.00	0.27	0.27	0.05	0.10	4.32
1988	0.25	0.58	0.44	5.04	0.49	0.83	0.09	0.01	0.12	0.02	7.87
1989	0.00	0.31	2.23	0.61	3.04	0.42	0.71	0.18	0.02	0.20	7.73
1990	0.04	0.08	0.67	3.14	1.09	1.18	0.28	0.31	0.03	0.04	6.89
1991	0.39	1.31	1.12	0.93	1.63	0.83	0.69	0.08	0.03	0.14	7.14
1992	0.00	0.15	1.20	0.63	0.19	0.47	0.27	0.29	0.05	0.09	3.34
1993	0.00	0.00	0.83	2.32	0.47	0.08	0.33	0.08	0.08	0.10	4.30
1994	0.07	0.10	0.37	0.29	0.36	0.09	0.02	0.06	0.00	0.01	1.38
1995	0.69	0.13	0.53	1.67	0.89	1.68	0.35	0.46	0.00	0.12	6.52
1996	0.00	0.25	0.54	1.79	2.42	0.22	0.17	0.05	0.00	0.00	5.44
1997	0.49	0.10	0.39	0.09	0.72	0.94	0.10	0.23	0.10	0.00	3.15
1998	0.10	0.00	2.00	3.82	1.91	1.89	1.17	0.06	0.06	0.00	11.01
1999	0.04	0.04	0.26	1.21	1.12	0.67	0.31	0.19	0.06	0.01	3.92
2000	0.07	0.00	0.55	1.16	2.43	0.89	0.25	0.09	0.04	0.00	5.47
2001	0.00	0.00	0.12	1.60	0.17	0.63	0.20	0.00	0.02	0.02	2.76
2002	0.07	0.00	0.23	0.90	2.08	0.34	0.41	0.12	0.00	0.00	4.15
2003	0.00	0.00	0.22	0.52	1.47	2.08	0.24	0.14	0.02	0.00	4.69
2004	0.00	0.99	0.02	1.51	3.77	3.80	2.44	0.43	0.69	0.05	13.70
2005	0.07	0.03	0.62	0.13	1.35	0.52	0.34	0.24	0.06	0.00	3.35
2006	0.00	0.07	0.13	1.72	0.74	1.82	0.61	0.27	0.14	0.00	5.50
2007	0.00	0.00	0.67	0.56	4.07	0.43	0.53	0.08	0.05	0.00	6.39

Table 9. Indices of abundance (numbers/standard tow) of eastern Georges Bank cod from the NMFS autumn survey.

	Age Group										
Year	0	1	2	3	4	5	6	7	8	9+	Total
1970	0.63	2.55	1.51	0.38	0.74	0.02	0.00	0.00	0.01	0.05	5.88
1971	0.37	2.07	1.62	0.33	0.42	0.24	0.26	0.03	0.00	0.00	5.32
1972	2.00	5.95	1.11	1.20	0.04	0.07	0.00	0.00	0.00	0.00	10.38
1973	0.09	4.59	5.55	1.88	1.84	0.17	0.00	0.05	0.12	0.00	14.29
1974	0.15	0.38	0.77	1.20	0.10	0.06	0.03	0.00	0.00	0.00	2.68
1975	0.75	1.19	0.32	0.75	1.38	0.05	0.08	0.00	0.00	0.00	4.51
1976	0.00	15.88	0.70	0.28	0.00	0.18	0.00	0.09	0.00	0.00	17.12
1977	0.09	0.00	6.27	1.29	0.33	0.28	0.32	0.01	0.00	0.00	8.59
1978	0.20	2.74	0.10	5.46	0.75	0.10	0.11	0.14	0.00	0.00	9.62
1979	0.33	3.07	3.06	0.21	2.75	0.44	0.09	0.04	0.02	0.03	10.02
1980	0.58	1.41	0.74	1.17	0.04	0.33	0.03	0.03	0.04	0.00	4.36
1981	0.65	4.24	2.18	1.68	0.49	0.03	0.05	0.00	0.00	0.10	9.42
1982	0.00	0.99	1.30	0.10	0.11	0.00	0.00	0.05	0.00	0.00	2.54
1983	1.67	0.12	0.33	1.25	0.04	0.00	0.00	0.00	0.04	0.00	3.46
1984	0.05	3.26	0.22	1.19	1.89	0.05	0.07	0.00	0.00	0.02	6.74
1985	2.25	0.38	1.79	0.29	0.03	0.01	0.02	0.00	0.00	0.01	4.77
1986	0.21	5.44	0.10	0.36	0.00	0.00	0.01	0.00	0.00	0.00	6.13
1987	0.28	0.23	1.52	0.22	0.18	0.00	0.00	0.00	0.00	0.01	2.45
1988	0.17	1.01	0.32	2.13	0.29	0.37	0.00	0.05	0.07	0.02	4.44
1989	0.57	1.03	2.41	0.40	1.09	0.14	0.04	0.00	0.00	0.00	5.69
1990	0.36	0.73	0.88	1.42	0.21	0.36	0.05	0.00	0.03	0.00	4.03
1991	0.00	0.35	0.14	0.16	0.02	0.05	0.00	0.00	0.00	0.00	0.72
1992	0.00	0.37	1.31	0.28	0.00	0.07	0.02	0.00	0.00	0.00	2.05
1993	0.00	0.15	0.19	0.29	0.03	0.00	0.00	0.00	0.00	0.00	0.65
1994	0.02	0.15	0.53	0.41	0.27	0.02	0.05	0.00	0.00	0.00	1.44
1995	0.40	0.05	0.23	0.56	0.09	0.05	0.01	0.00	0.00	0.00	1.41
1996	0.02	0.56	0.15	0.56	0.41	0.10	0.05	0.00	0.00	0.00	1.85
1997	0.00	0.27	0.69	0.27	0.15	0.20	0.05	0.00	0.00	0.00	1.64
1998	0.00	0.23	1.16	1.06	0.17	0.22	0.00	0.00	0.06	0.00	2.90
1999	0.00	0.03	0.03	0.45	0.22	0.06	0.00	0.00	0.00	0.00	0.78
2000	0.05	0.10	0.37	0.12	0.16	0.08	0.00	0.00	0.00	0.00	0.89
2001	0.04	0.13	0.19	0.46	0.07	0.14	0.02	0.02	0.00	0.00	1.08
2002	0.22	0.20	1.14	1.28	4.51	0.31	0.38	0.03	0.00	0.00	8.07
2003	0.14	0.00	0.04	0.18	0.13	0.03	0.00	0.01	0.00	0.00	0.53
2004	0.20	0.76	0.12	1.52	0.70	0.98	0.79	0.19	0.05	0.05	5.36
2005	0.04	0.05	0.92	0.21	0.45	0.08	0.00	0.02	0.00	0.00	1.76
2006	0.00	0.28	0.24	1.02	0.07	0.51	0.03	0.03	0.03	0.03	2.23

Table 10. Average weight at age (kg) for eastern Georges Bank cod from the DFO survey.

	Age Group										
Year	1	2	3	4	5	6	7	8	9	10	11
1978[1]	0.13	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	13.04	16.81
1979[1]	0.13	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	13.04	16.81
1980[1]	0.13	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	13.04	16.81
1981[1]	0.13	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	13.04	16.81
1982[1]	0.13	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	13.04	16.81
1983[1]	0.13	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	13.04	16.81
1984[1]	0.13	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	13.04	16.81
1985[1]	0.13	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	13.04	16.81
1986	0.12	0.81	1.70	2.78	4.20	6.22	7.31	9.31	13.86	14.15	16.81
1987	0.15	0.85	1.70	2.69	5.67	7.49	7.48	6.66	10.10	7.00	16.81
1988	0.15	0.93	1.79	3.02	4.17	6.27	8.44	8.72	12.33	14.16	11.40
1989	0.14	0.83	1.70	2.76	4.31	6.43	7.62	7.81	11.32	10.30	14.72
1990	0.21	0.79	1.84	2.90	4.36	6.00	8.59	9.52	13.49	14.41	17.97
1991	0.09	0.90	1.95	3.17	4.24	4.90	7.54	10.06	9.97	15.50	13.49
1992	0.12	0.82	1.94	2.88	4.19	5.89	6.58	8.59	9.91	11.95[2]	24.60
1993	0.07	0.95	1.84	2.92	4.44	5.81	6.75	7.40	9.28	8.41	21.63[2]
1994	0.06	0.66	1.41	2.65	3.99	7.61	7.70	8.66	8.87	18.41	21.63[2]
1995	0.17	0.78	1.54	2.11	3.29	5.00	6.33	7.92	11.89	14.99	18.65
1996	0.05	0.76	1.56	2.56	4.00	6.11	5.55	12.03	11.92	13.79	19.75
1997	0.11	0.72	1.68	2.17	3.19	6.39	6.74	11.29	10.17	16.59	17.67
1998	0.08	0.61	1.29	2.22	3.09	4.64	5.77	8.40	8.21	8.25	15.59
1999	0.16	1.03	1.33	2.18	2.98	4.65	6.93	11.00	8.45	16.92	14.83
2000	0.08[2]	0.91	1.59	2.30	3.12	4.60	6.51	8.28	11.52	13.88	14.14
2001	0.01	0.68	1.40	2.44	3.59	5.14	6.91	7.47	10.25	9.85	11.76
2002	0.01	0.42	1.17	2.31	3.59	4.41	5.95	8.44	10.00	11.84	15.76
2003	0.01	0.18	1.03	1.79	3.09	3.48	5.24	6.81	7.66	10.44[2]	14.33[2]
2004	0.02	0.23	1.45	2.34	3.67	4.28	4.59	6.77	10.54	9.03	14.33[2]
2005	0.01	0.60	1.18	1.70	2.90	3.37	3.96	6.90	6.45	4.61	12.90
2006	0.03[2]	0.31	1.14	1.45	2.55	3.19	4.40	4.61	5.73	6.90	6.12
2007	0.05	0.55	1.05	1.86	2.59	4.27	6.13	6.98	7.98	6.90[2]	6.02
Min.	0.01	0.18	1.03	1.45	2.55	3.19	3.96	4.61	5.73	4.61	6.02
Max.	0.21	1.03	1.95	3.17	5.67	7.61	8.59	12.03	13.49	18.41	24.60
Avg.[3]	0.03	0.49	1.12	1.67	2.68	3.61	4.83	6.16	6.72	6.14	8.35

[1]average of 1986 to 1995 observed values
[2]average of adjacent years
[3]for 2005-2007

Table 11. Statistical properties of estimates for population abundance (numbers in thousands) and survey calibration constants for eastern Georges Bank cod obtained from a bootstrap with 1000 replications.

Parameter	Estimate	Standard Error	Relative Error	Bias	Relative Bias
N[1999 11]	33	21	0.631	4	0.108
N[2000 11]	43	25	0.579	4	0.098
N[2001 11]	74	40	0.532	7	0.089
N[2002 11]	40	23	0.577	3	0.063
N[2003 11]	91	50	0.548	7	0.078
N[2004 11]	92	42	0.453	5	0.055
N[2005 11]	110	47	0.429	5	0.047
N[2006 11]	124	51	0.414	5	0.044
N[2007 2]	1978	1102	0.557	240	0.121
N[2007 3]	693	270	0.389	63	0.090
N[2007 4]	4280	1388	0.324	291	0.068
N[2007 5]	367	120	0.328	10	0.026
N[2007 6]	764	231	0.303	36	0.047
N[2007 7]	404	122	0.301	12	0.030
N[2007 8]	307	99	0.323	16	0.051
N[2007 9]	274	111	0.406	10	0.036
N[2007 10]	78	37	0.479	4	0.050
N[2007 11]	187	84	0.448	13	0.068
DFO 2	0.254	0.051	0.201	0.003	0.011
DFO 3	1.081	0.215	0.199	0.008	0.007
DFO 4	1.783	0.346	0.194	0.014	0.008
DFO 5	2.388	0.481	0.201	0.021	0.009
DFO 6	2.362	0.472	0.200	0.031	0.013
DFO 7	2.104	0.453	0.215	0.077	0.036
NMFS spring Y41 1	0.033	0.017	0.497	0.003	0.080
NMFS spring Y41 2	0.397	0.247	0.623	0.058	0.145
NMFS spring Y41 3	0.473	0.245	0.519	0.042	0.088
NMFS spring Y41 4	0.465	0.225	0.483	0.032	0.068
NMFS spring Y41 5	0.742	0.396	0.533	0.084	0.114
NMFS spring Y41 6	0.837	0.414	0.495	0.070	0.084
NMFS spring Y41 7	1.364	0.744	0.545	0.140	0.103
NMFS spring Y41 8	1.431	0.749	0.524	0.153	0.107
NMFS spring Y36 1	0.045	0.010	0.222	0.001	0.021
NMFS spring Y36 2	0.186	0.033	0.179	0.003	0.015
NMFS spring Y36 3	0.502	0.091	0.181	0.010	0.019
NMFS spring Y36 4	0.833	0.150	0.181	0.005	0.006
NMFS spring Y36 5	1.002	0.188	0.188	0.020	0.020
NMFS spring Y36 6	0.843	0.161	0.191	0.021	0.025
NMFS spring Y36 7	0.762	0.146	0.192	0.019	0.025
NMFS spring Y36 8	0.615	0.130	0.211	0.020	0.033
NMFS autumn 1	0.096	0.017	0.172	0.001	0.007
NMFS autumn 2	0.133	0.023	0.172	0.001	0.008
NMFS autumn 3	0.242	0.040	0.165	0.002	0.008
NMFS autumn 4	0.173	0.030	0.176	0.002	0.013
NMFS autumn 5	0.170	0.034	0.203	0.004	0.023

Table 12. Beginning of year population abundance (numbers in thousands) for eastern Georges Bank cod.

Year	Age Group											
	1	2	3	4	5	6	7	8	9	10	11	1+
1978	11131	2210	10563	3506	991	307	279	56	26	9	0	29078
1979	9504	9112	1700	5432	1905	536	152	154	27	11	4	28538
1980	9231	7772	6714	1028	2830	1062	303	105	85	19	6	29154
1981	17355	7557	5467	4143	601	1490	558	149	68	39	10	37438
1982	6287	14192	5638	3167	2260	352	682	304	64	23	16	32984
1983	4581	5142	9196	3097	1312	895	119	250	108	19	8	24727
1984	13532	3715	3022	4462	1217	655	478	70	140	54	10	27355
1985	4532	11070	2797	1652	2438	536	276	185	29	50	20	23586
1986	21113	3699	6543	1194	785	1150	238	139	62	11	17	34953
1987	7033	17261	2733	3381	515	368	581	142	79	28	6	32126
1988	13652	5746	10835	1461	1782	293	193	325	83	43	16	34430
1989	4102	11168	4418	5624	624	697	112	68	140	32	18	27004
1990	5743	3315	8404	3016	2965	339	293	42	33	69	16	24235
1991	9196	4694	2067	4002	1603	1355	173	130	26	15	36	23296
1992	2726	7499	3191	974	1542	466	407	59	56	5	6	16930
1993	3971	2144	3936	1492	411	456	159	126	26	22	2	12747
1994	2793	3244	1343	1452	498	144	80	33	21	1	3	9611
1995	2117	2284	2487	662	517	188	81	13	4	0	0	8354
1996	3224	1732	1819	1824	434	343	141	63	8	2	0	9590
1997	4778	2636	1380	1274	1134	284	236	105	49	5	1	11883
1998	1762	3909	2035	938	674	515	133	143	69	37	4	10218
1999	4450	1442	3107	1323	589	371	272	85	104	52	29	11825
2000	2578	3640	1124	2058	756	383	248	176	59	83	39	11144
2001	2158	2109	2926	815	1382	502	283	185	133	46	68	10609
2002	3027	1765	1625	1971	487	795	323	205	136	104	37	10476
2003	1036	2475	1431	1213	1274	310	519	241	161	108	84	8853
2004	7747	847	1998	1011	744	690	188	351	183	129	87	13977
2005	972	6340	681	1516	691	489	449	125	268	146	105	11781
2006	2129	794	5128	516	1084	527	374	340	93	215	118	11319
2007	2500	1738	631	3989	357	728	393	291	264	74	175	11139

Table 13. Annual fishing mortality rate for eastern Georges Bank cod.

Year	Age Group										
	1	2	3	4	5	6	7	8	9	10	4-6
1978	0.00	0.06	0.47	0.41	0.41	0.50	0.39	0.53	0.65	0.57	0.42
1979	0.00	0.11	0.30	0.45	0.38	0.37	0.18	0.39	0.17	0.36	0.43
1980	0.00	0.15	0.28	0.34	0.44	0.44	0.51	0.24	0.57	0.38	0.42
1981	0.00	0.09	0.35	0.41	0.34	0.58	0.41	0.65	0.88	0.72	0.44
1982	0.00	0.23	0.40	0.68	0.73	0.88	0.81	0.83	1.00	0.86	0.71
1983	0.01	0.33	0.52	0.73	0.49	0.43	0.34	0.38	0.50	0.41	0.62
1984	0.00	0.08	0.40	0.40	0.62	0.67	0.75	0.67	0.83	0.78	0.47
1985	0.00	0.33	0.65	0.54	0.55	0.61	0.48	0.89	0.77	0.88	0.56
1986	0.00	0.10	0.46	0.64	0.56	0.48	0.31	0.37	0.61	0.44	0.56
1987	0.00	0.27	0.43	0.44	0.37	0.45	0.38	0.34	0.40	0.36	0.43
1988	0.00	0.06	0.46	0.65	0.74	0.76	0.84	0.65	0.76	0.67	0.70
1989	0.01	0.08	0.18	0.44	0.41	0.67	0.77	0.51	0.51	0.51	0.46
1990	0.00	0.27	0.54	0.43	0.58	0.47	0.61	0.30	0.63	0.45	0.51
1991	0.00	0.19	0.55	0.75	1.04	1.00	0.88	0.64	1.38	0.76	0.87
1992	0.04	0.44	0.56	0.65	1.02	0.87	0.97	0.62	0.73	0.67	0.88
1993	0.00	0.27	0.79	0.89	0.80	1.55	1.39	1.59	2.91	1.82	1.00
1994	0.00	0.07	0.50	0.81	0.73	0.31	1.56	1.90	6.10	3.55	0.76
1995	0.00	0.03	0.11	0.22	0.20	0.08	0.04	0.26	0.51	0.32	0.19
1996	0.00	0.03	0.15	0.27	0.22	0.16	0.08	0.03	0.25	0.06	0.25
1997	0.00	0.06	0.18	0.43	0.57	0.52	0.25	0.17	0.05	0.15	0.50
1998	0.00	0.03	0.23	0.25	0.37	0.40	0.20	0.09	0.04	-0.01	0.33
1999	0.00	0.05	0.21	0.35	0.21	0.18	0.20	0.11	0.01	0.04	0.29
2000	0.00	0.02	0.12	0.19	0.20	0.09	0.08	0.06	0.00	-0.01	0.18
2001	0.00	0.06	0.19	0.31	0.34	0.22	0.10	0.09	0.01	-0.01	0.31
2002	0.00	0.01	0.09	0.23	0.24	0.21	0.08	0.03	0.02	-0.01	0.23
2003	0.00	0.01	0.14	0.28	0.39	0.27	0.17	0.06	0.02	0.01	0.33
2004	0.00	0.02	0.07	0.17	0.21	0.21	0.18	0.06	0.02	0.01	0.19
2005	0.00	0.01	0.07	0.13	0.06	0.06	0.07	0.07	0.02	0.01	0.10
2006	0.00	0.03	0.05	0.15	0.19	0.09	0.05	0.05	0.02	0.01	0.15

Table 14. Beginning of year population biomass (thousands of mt) for eastern Georges Bank cod.

Year	Age Group												
	1	2	3	4	5	6	7	8	9	10	11	1+	3+
1978	1440	1838	18395	9770	4247	1889	2073	473	294	117	2	40539	37261
1979	1229	7577	2961	15138	8165	3302	1133	1303	300	146	76	41330	32524
1980	1194	6463	11692	2864	12131	6546	2250	886	943	242	116	45326	37669
1981	2245	6283	9521	11545	2578	9179	4148	1266	750	511	188	48214	39685
1982	813	11801	9818	8827	9687	2168	5069	2571	708	297	283	52041	39427
1983	593	4276	16015	8630	5622	5515	885	2113	1201	247	143	45240	40372
1984	1750	3089	5262	12436	5214	4038	3555	589	1559	694	186	38375	33535
1985	586	9205	4871	4603	10452	3305	2050	1567	323	648	364	37975	28184
1986	2555	2982	11124	3323	3298	7151	1739	1298	861	156	308	34794	29257
1987	1055	14586	4649	9079	2924	2758	4342	947	797	194	104	41435	25794
1988	2078	5347	19343	4414	7431	1835	1629	2839	1026	615	181	46737	39312
1989	583	9291	7532	15515	2688	4486	855	531	1581	330	268	43661	33787
1990	1233	2610	15488	8744	12936	2034	2513	403	451	991	283	47686	43844
1991	807	4209	4033	12675	6803	6633	1306	1309	256	226	486	38743	33727
1992	335	6137	6176	2802	6462	2746	2677	507	559	63	137	28601	22129
1993	279	2047	7227	4352	1825	2653	1073	934	241	188	48	20866	18541
1994	179	2140	1897	3847	1985	1095	613	282	186	21	64	12310	9990
1995	357	1793	3841	1397	1704	940	514	106	45	1	0	10699	8549
1996	147	1308	2834	4672	1733	2098	781	754	99	24	0	14450	12995
1997	532	1900	2315	2767	3619	1817	1593	1181	498	86	24	16331	13899
1998	137	2393	2624	2078	2080	2393	765	1204	567	303	56	14600	12069
1999	694	1483	4145	2884	1757	1724	1886	934	878	884	431	17701	15523
2000	214	3295	1789	4731	2360	1764	1617	1456	675	1155	547	19602	16092
2001	22	1444	4089	1993	4960	2582	1953	1382	1363	457	798	21043	19577
2002	39	748	1909	4545	1748	3506	1921	1729	1360	1231	590	19327	18541
2003	13	446	1477	2167	3937	1080	2720	1640	1234	1127	1200	17041	16582
2004	121	193	2906	2361	2736	2952	865	2380	1927	1166	1251	18858	18544
2005	11	3807	803	2577	2005	1648	1780	860	1726	673	1354	17243	13426
2006	69	250	5868	748	2767	1682	1644	1568	533	1483	725	17337	17018
2007	134	952	661	7432	924	3111	2408	2031	2105	512	1050	21321	20234

Table 15. Projection inputs for eastern Georges Bank cod.

	Age Group										
	1	2	3	4	5	6	7	8	9	10	11
Natural Mortality											
2007-2008	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fishery Partial Recruitment											
2007-2008	0.01	0.1	0.5	1	1	1	0.7	0.5	0.1	0.05	0.05
Fishery Weight at Age											
2007-2008	0.40	1.03	1.84	2.57	3.48	4.53	5.58	6.68	8.16	8.49	12.32
Population Beginning of Year Weight at Age											
2008-2009	0.03	0.49	1.12	1.67	2.68	3.61	4.83	6.16	6.72	6.14	8.35

Table 16. Deterministic projection results for eastern Georges Bank cod.

	Age Group												
	1	2	3	4	5	6	7	8	9	10	11	1+	3+
Projected Population Numbers													
2008	2500	2044	1406	486	2897	259	529	296	224	213	60		
2009	2500	2043	1644	1052	333	1981	177	382	221	180	173		
Fishing Mortality													
2007	0.001	0.012	0.06	0.12	0.12	0.12	0.084	0.06	0.012	0.006	0.006		
2008	0.002	0.018	0.09	0.18	0.18	0.18	0.126	0.09	0.018	0.009	0.009		
Projected Population Biomass													
2008	81	997	1579	813	7765	937	2554	1821	1507	1310	504	19869	18791
2009	81	996	1847	1758	892	7154	857	2351	1486	1107	1445	19974	18897
Projected Catch Numbers													
2007	3	19	33	409	37	75	29	15	3	0	1		
2008	4	33	110	73	434	39	57	23	4	2	0		
Projected Catch Biomass													
2007	1	19	61	1051	127	339	160	103	23	3	12	1900	
2008	2	34	202	187	1508	176	317	154	30	15	6	2630	

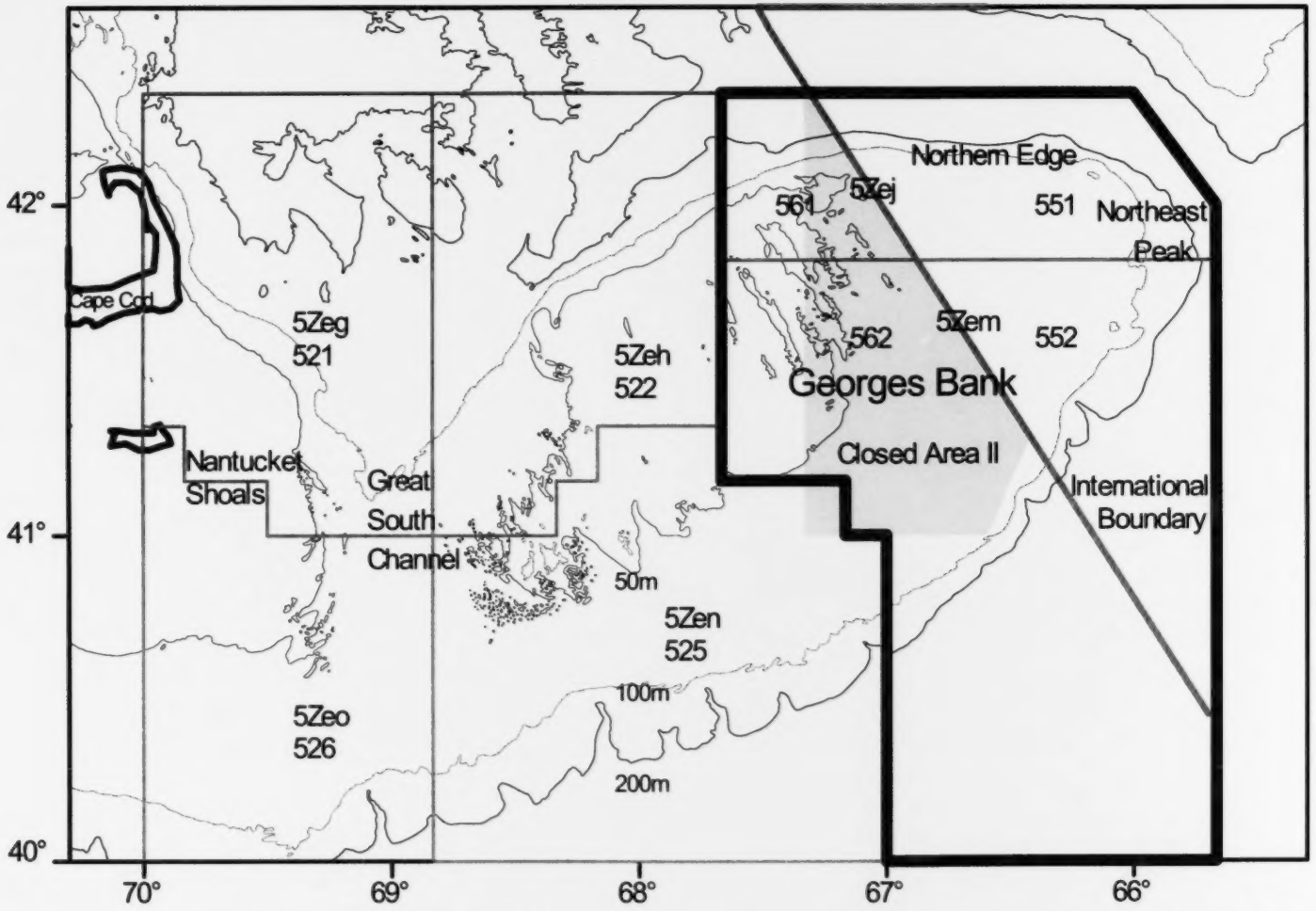

Figure 1. Fisheries statistical unit areas in NAFO Subdivision 5Ze. The eastern Georges Bank management unit is outlined by a heavy black line.

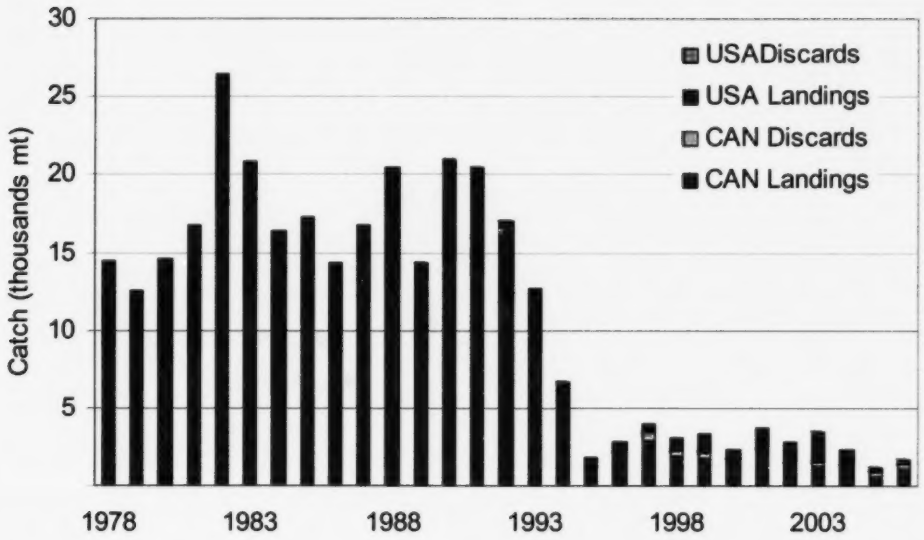

Figure 2. Catches (mt) of cod from eastern Georges Bank during 1978-2006.

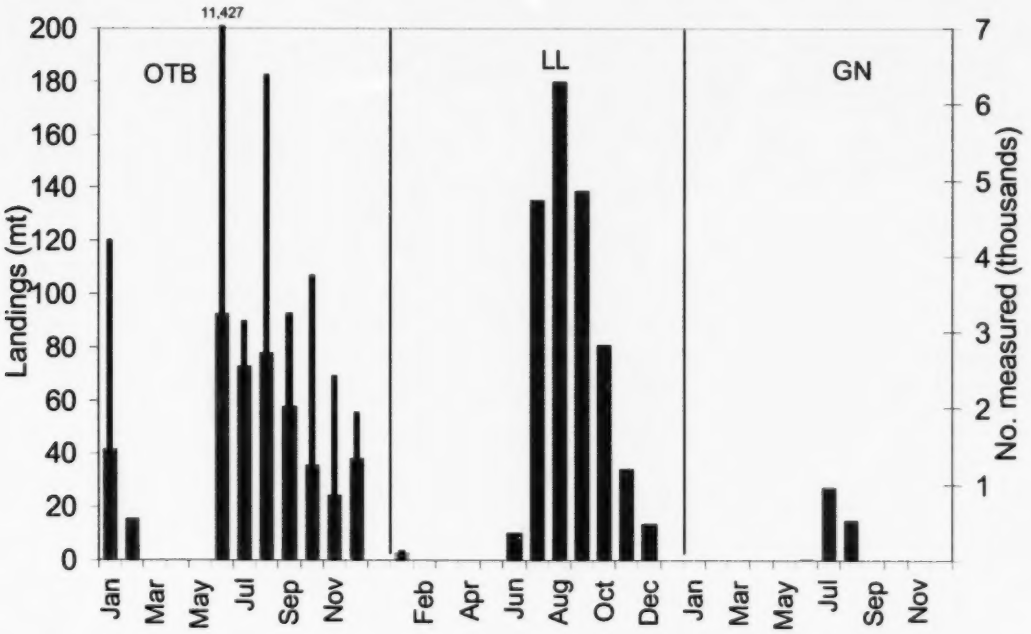

Figure 3. Landings (wide bars) and sampling (narrow dark bars) of cod by gear and month from the 2006 Canadian groundfish fishery on eastern Georges Bank.

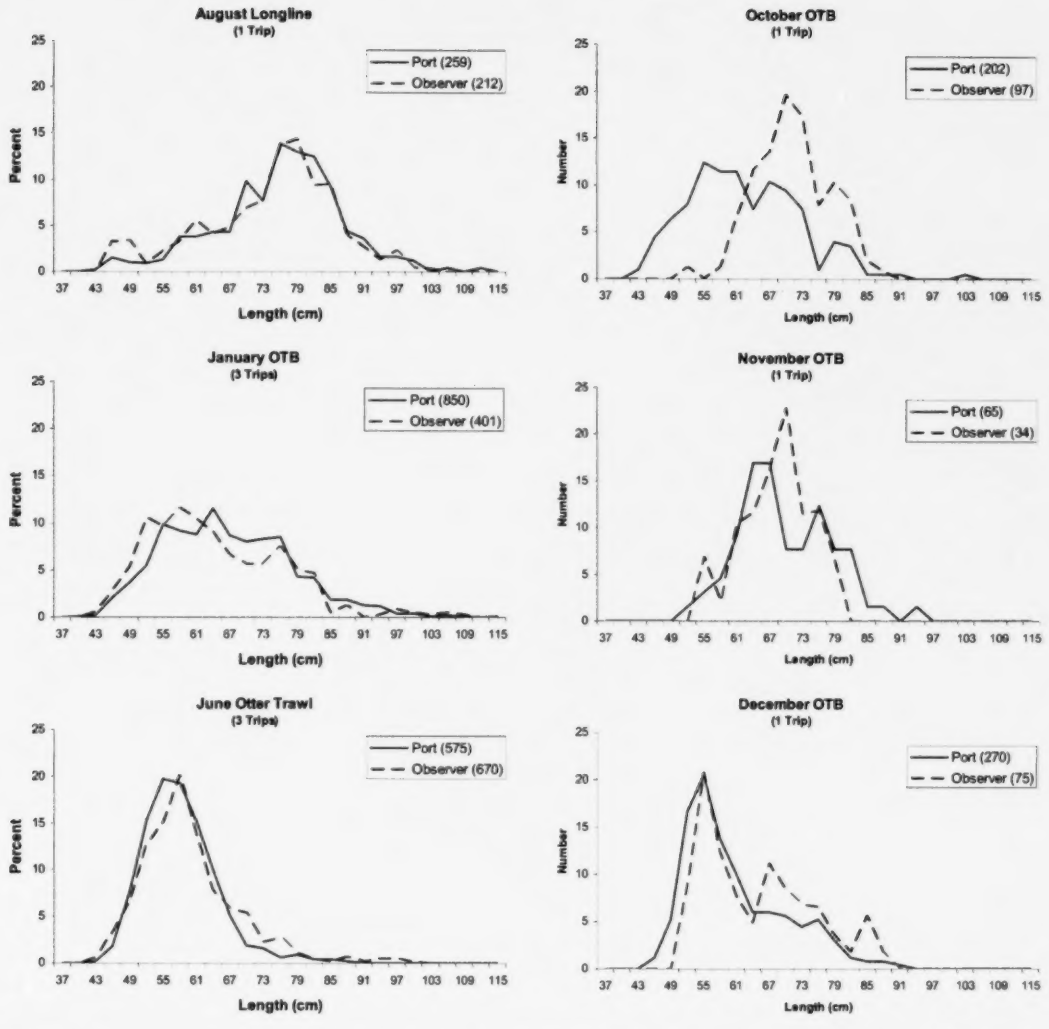

Figure 4. Comparison of cod length composition from port and sea sampling for the 2006 Canadian fishery on eastern Georges Bank.

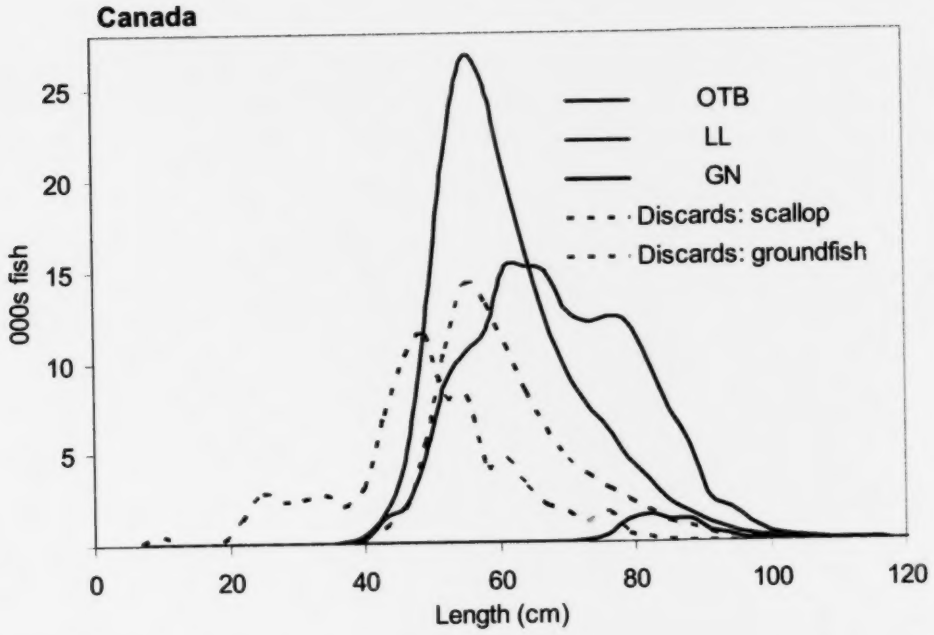

Figure 5. Cod catches at length by gear from the 2006 Canadian fisheries on eastern Georges Bank.

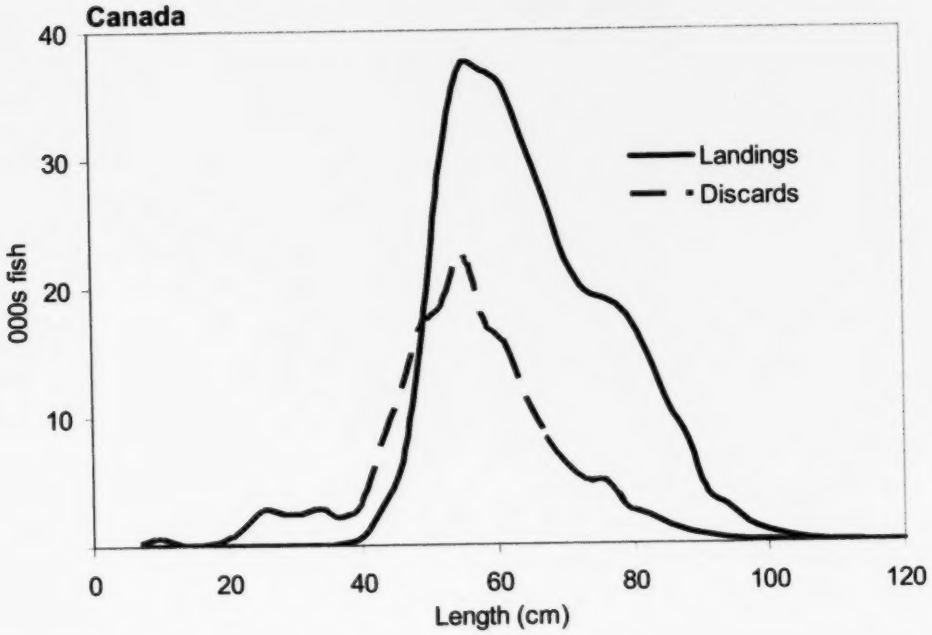

Figure 6. Cod landings and discards at length from the 2006 Canadian fisheries on eastern Georges Bank.

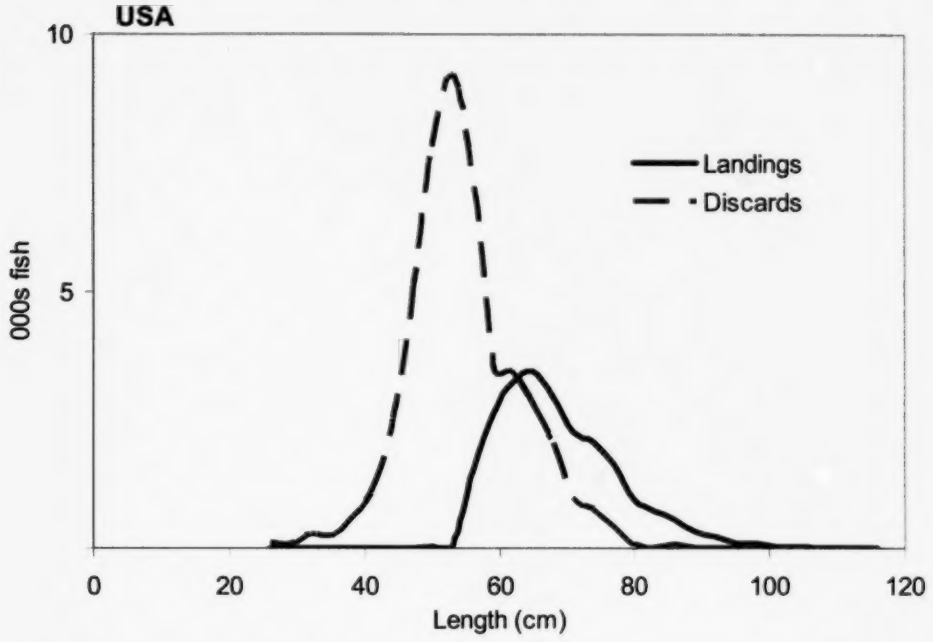

Figure 7. Cod landings and discards at length from the 2006 USA fisheries on eastern Georges Bank.

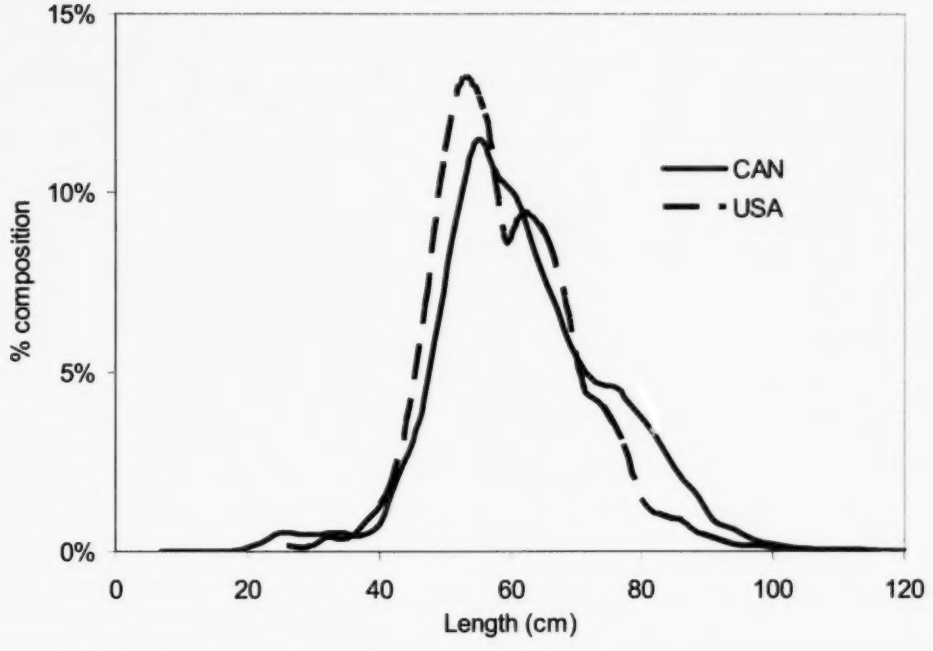

Figure 8. Catch composition from the 2006 Canadian and USA fisheries on eastern Georges Bank.

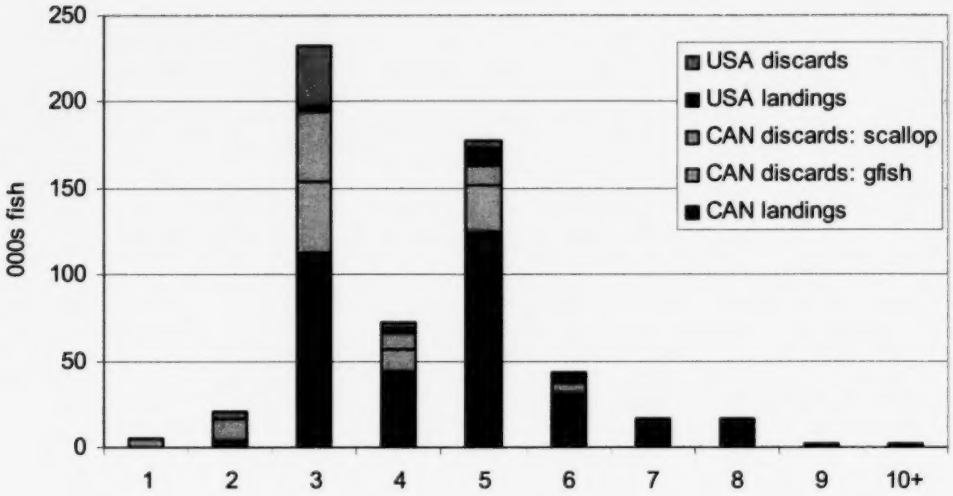

Figure 9. Catch at age for landings and discards of cod from the 2006 fisheries on eastern Georges Bank.

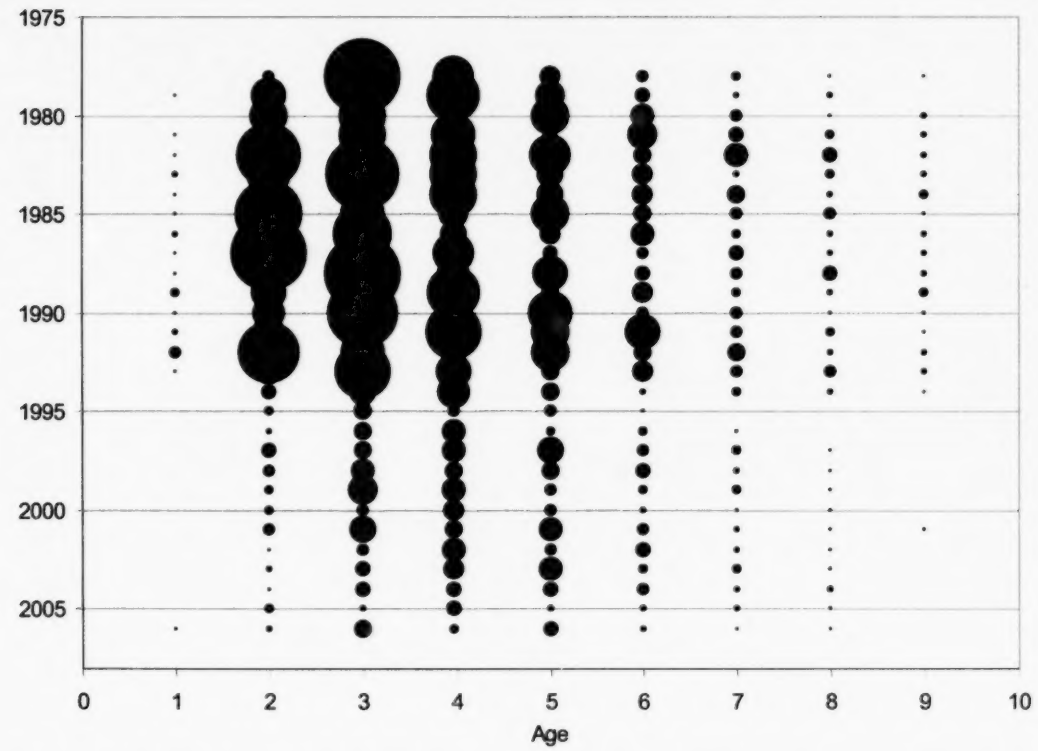

Figure 10. Total catch at age (numbers) of cod from eastern Georges Bank for 1978 to 2006. The bubble area is proportional to magnitude.

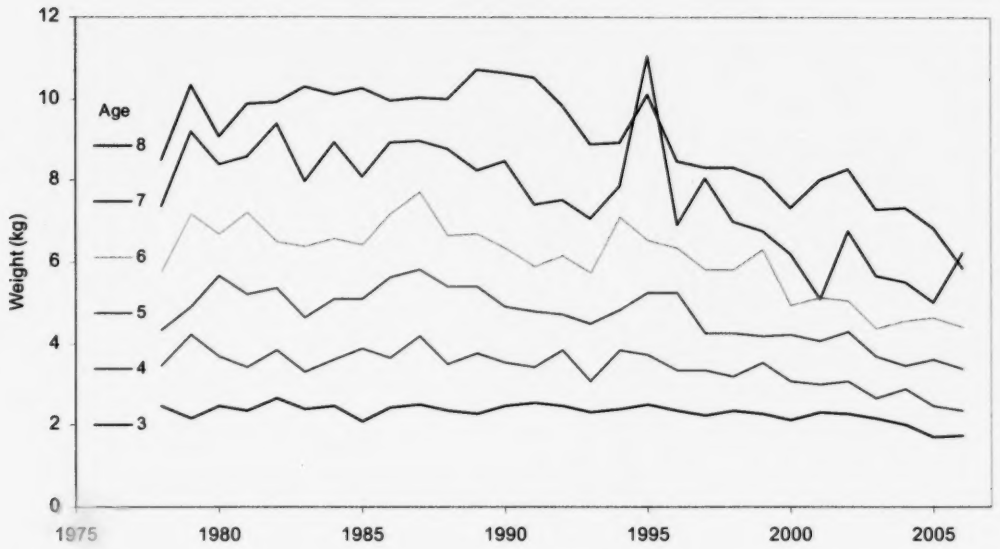

Figure 11. Average weights at ages 3 to 8 of cod from the eastern Georges Bank fishery for 1978 to 2006.

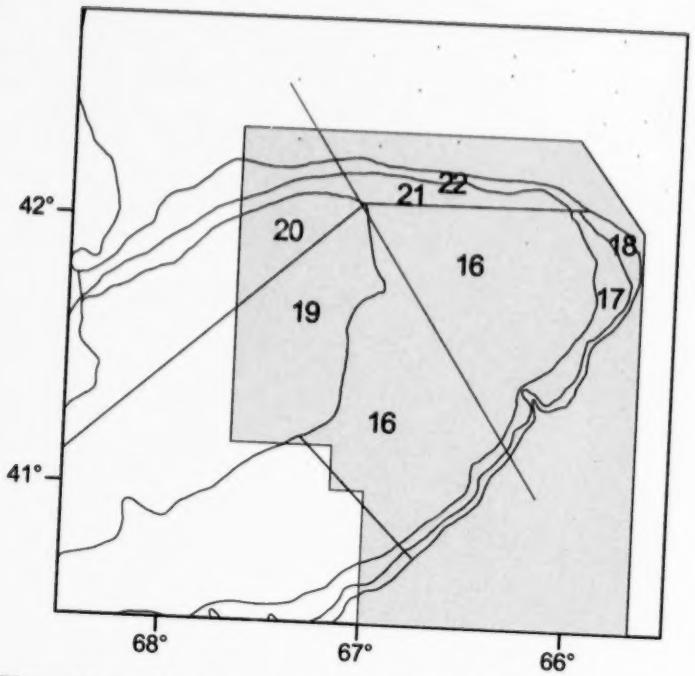

Figure 12. Stratification used for NMFS surveys. The eastern Georges Bank management unit is indicated by shading.

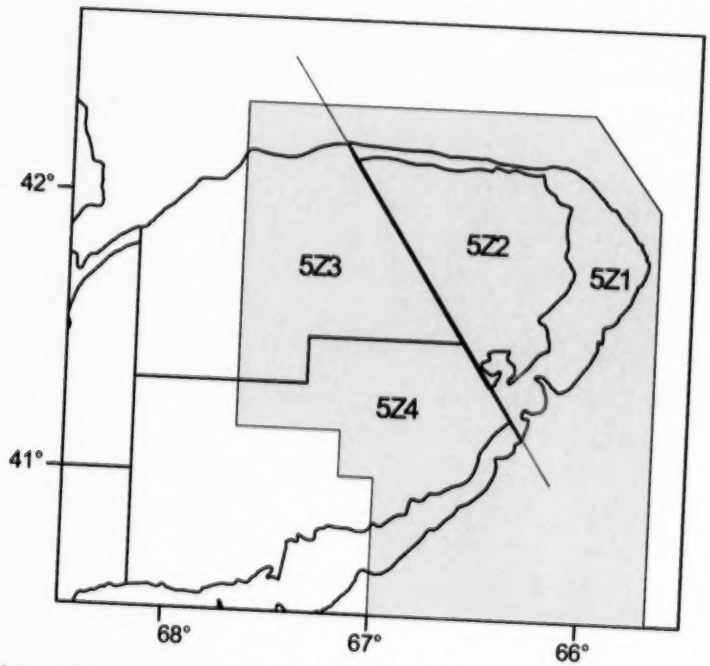

Figure 13. Stratification used for the DFO survey. The eastern Georges Bank management unit is indicated by shading.

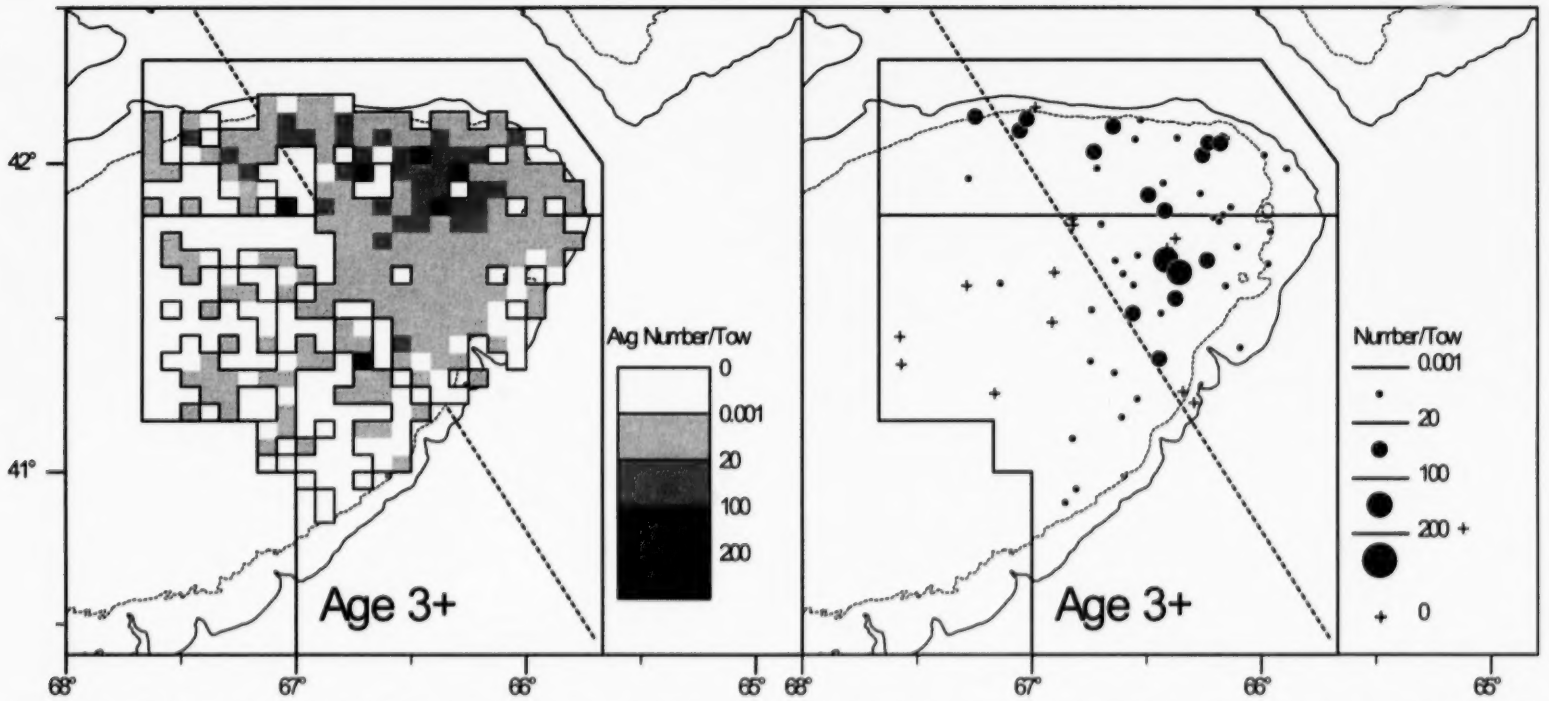

Figure 14. Spatial distribution of cod on eastern Georges Bank from the DFO survey for 2007 (right panel) compared to the average for 1997-2006 (left panel).

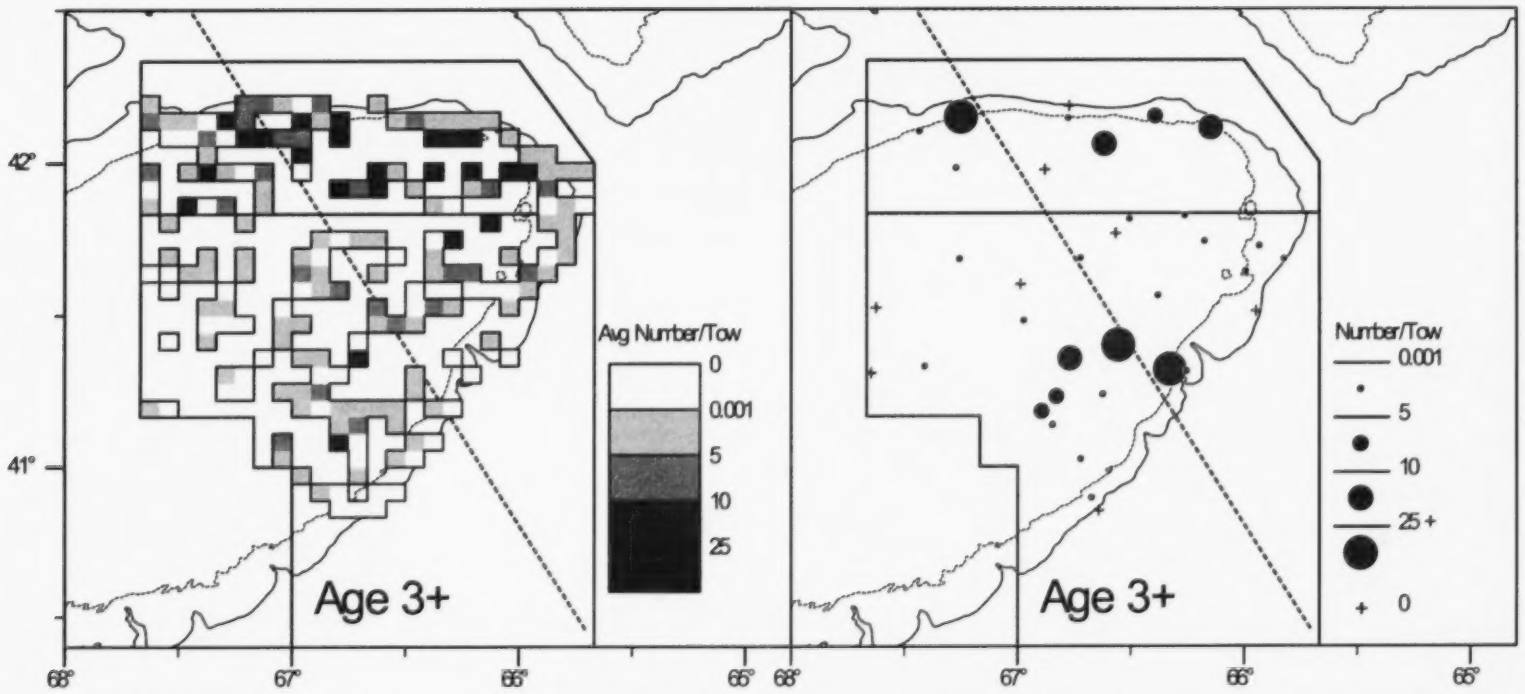

Figure 15. Spatial distribution of cod on eastern Georges Bank from the NMFS spring survey for 2007 (right panel) compared to the average for 1997-2006 (left panel).

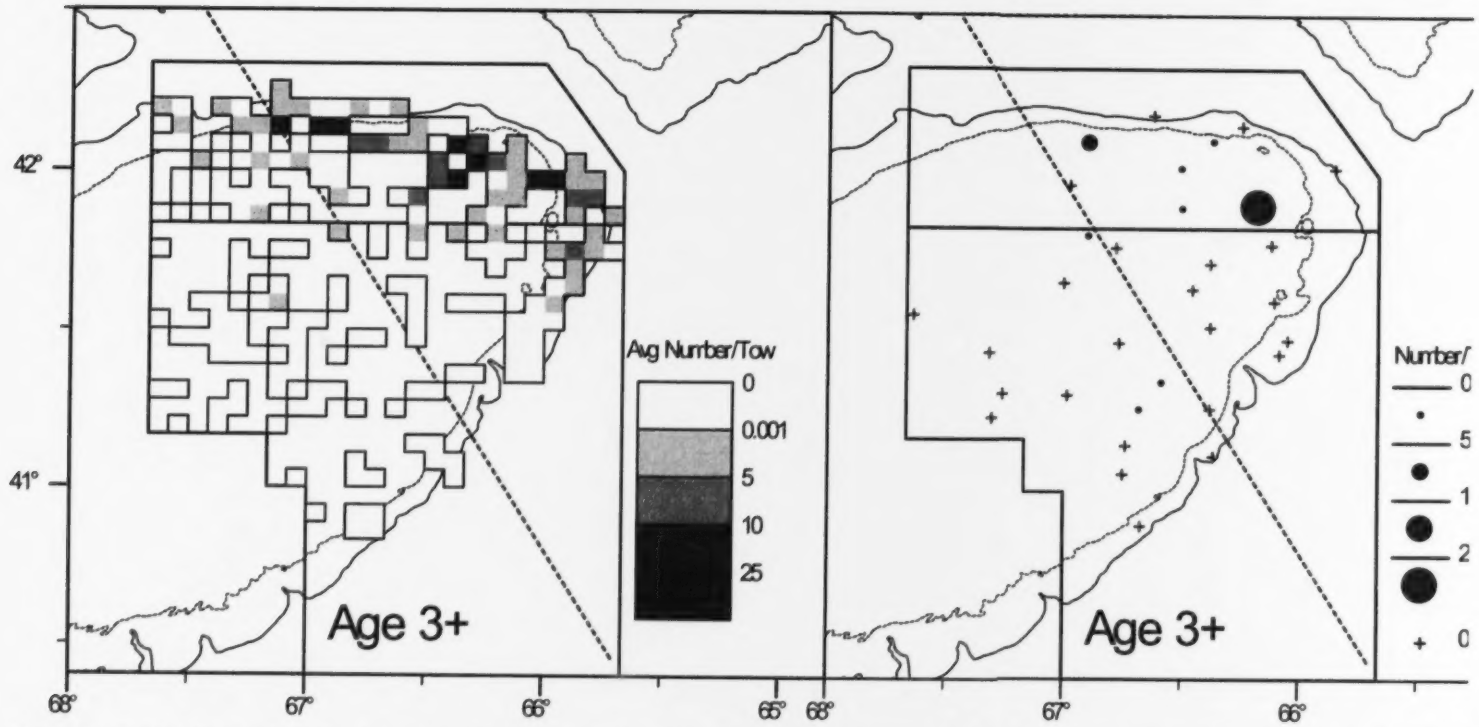

Figure 16. Spatial distribution of cod on eastern Georges Bank from the NMFS autumn survey for 2006 (right panel) compared to the average for 1996-2005 (left panel).

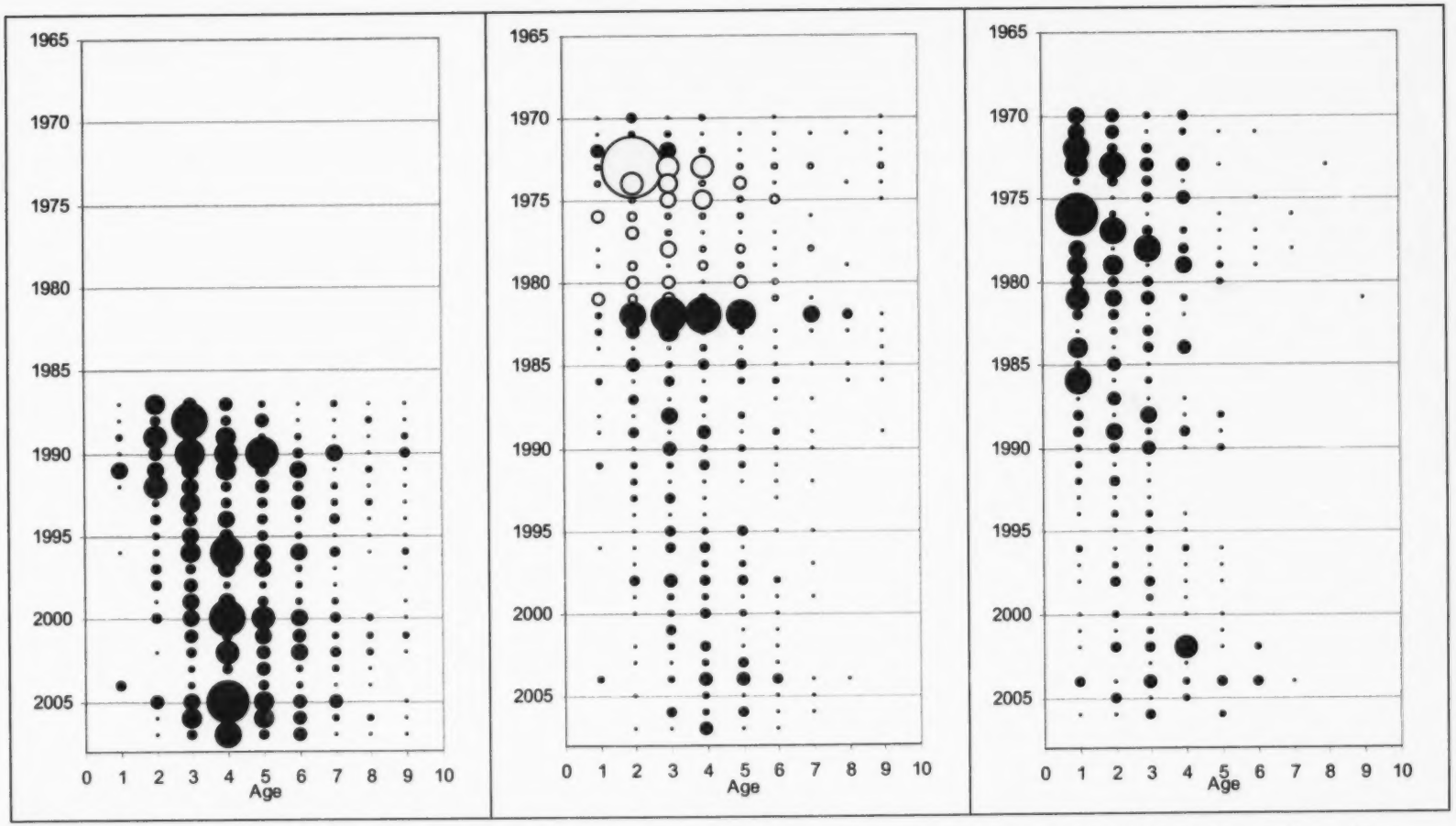

Figure 17. Survey abundance at age (numbers) of eastern Georges Bank cod. The bubble area is proportional to magnitude within each survey. Conversion factors to account for changes in door type and survey vessel were applied to the NMFS surveys. The NMFS spring survey was conducted using a modified Yankee 41 during 1978 to 1981 (pale bubbles). The 2003 year class is identified.

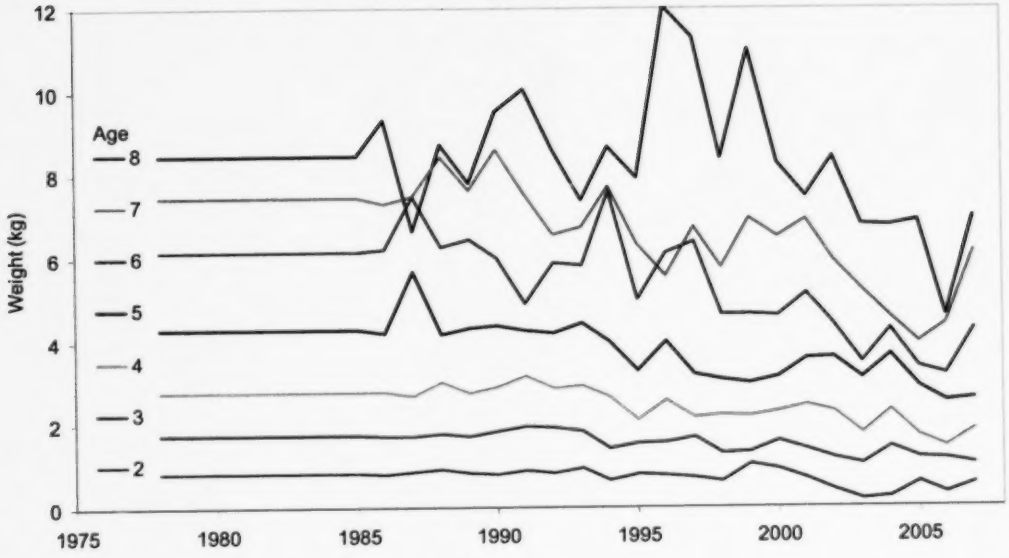

Figure 18. Average weights of eastern Georges Bank cod at ages 3 to 8 from the DFO survey. The average of 1986 to 1995 was used for 1978 to 1985 to calculate biomass.

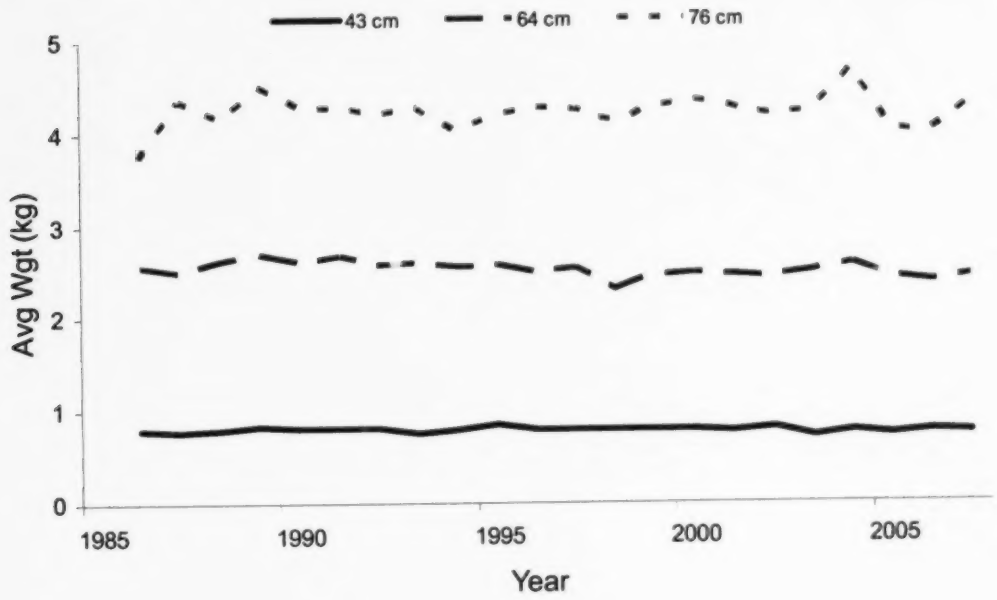

Figure 19. Condition, measured as average weight at three representative length groupings (center of 3 cm grouping used in label), for eastern Georges Bank cod from the DFO survey.

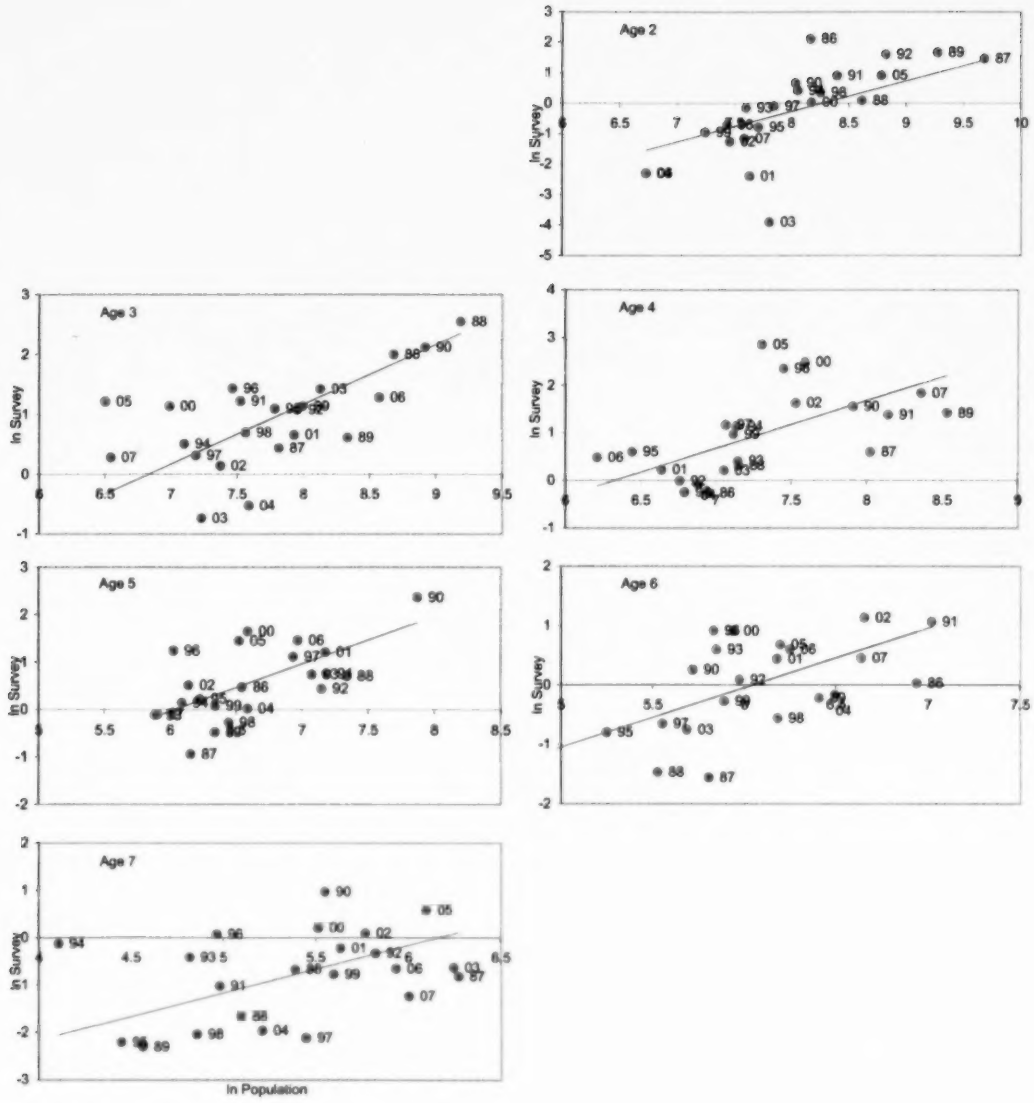

Figure 20. Observed and predicted *ln* DFO survey abundance versus *ln* population abundance for eastern Georges Bank cod.

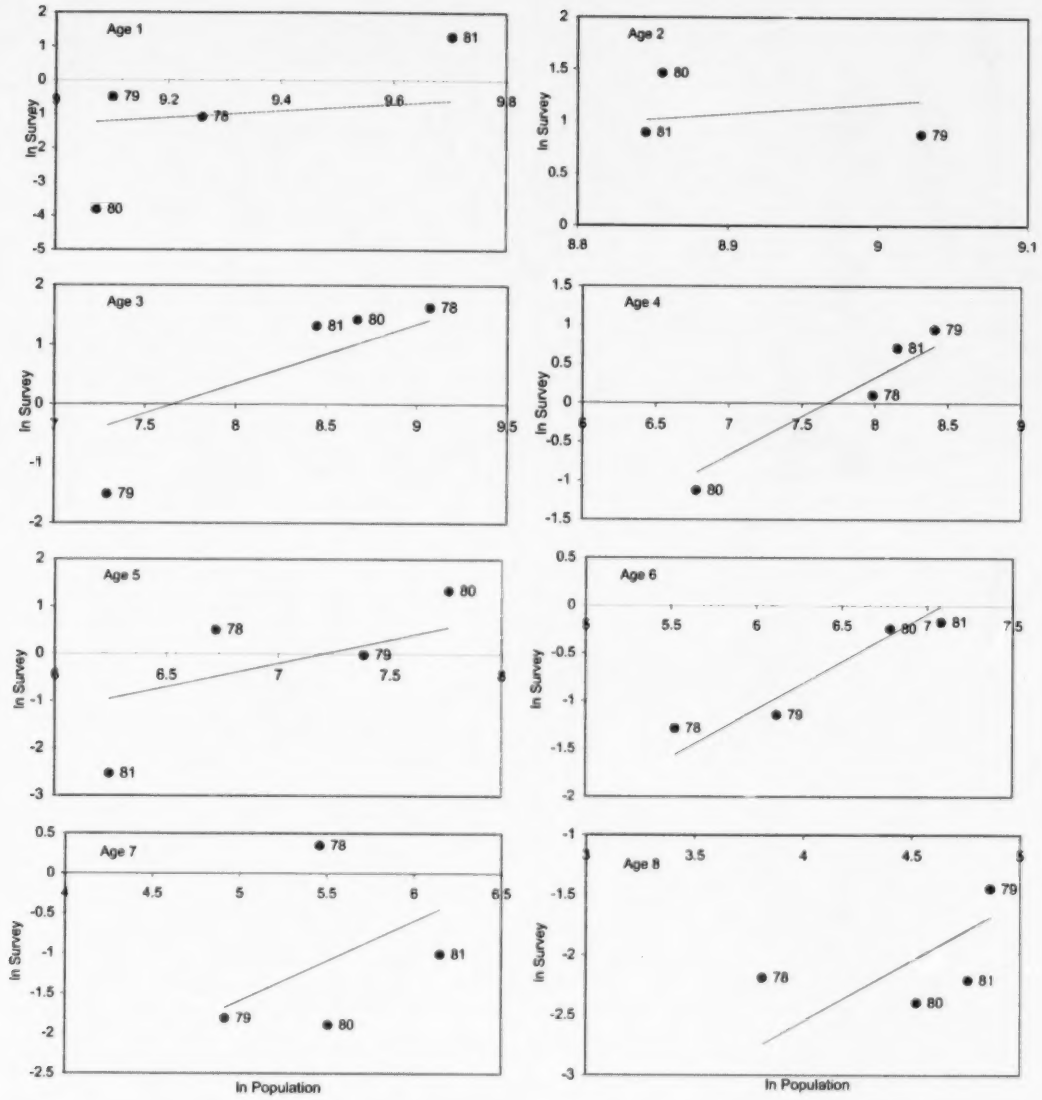

Figure 21. Observed and predicted *ln* NMFS spring Yankee 41 survey abundance versus *ln* population abundance for eastern Georges Bank cod.

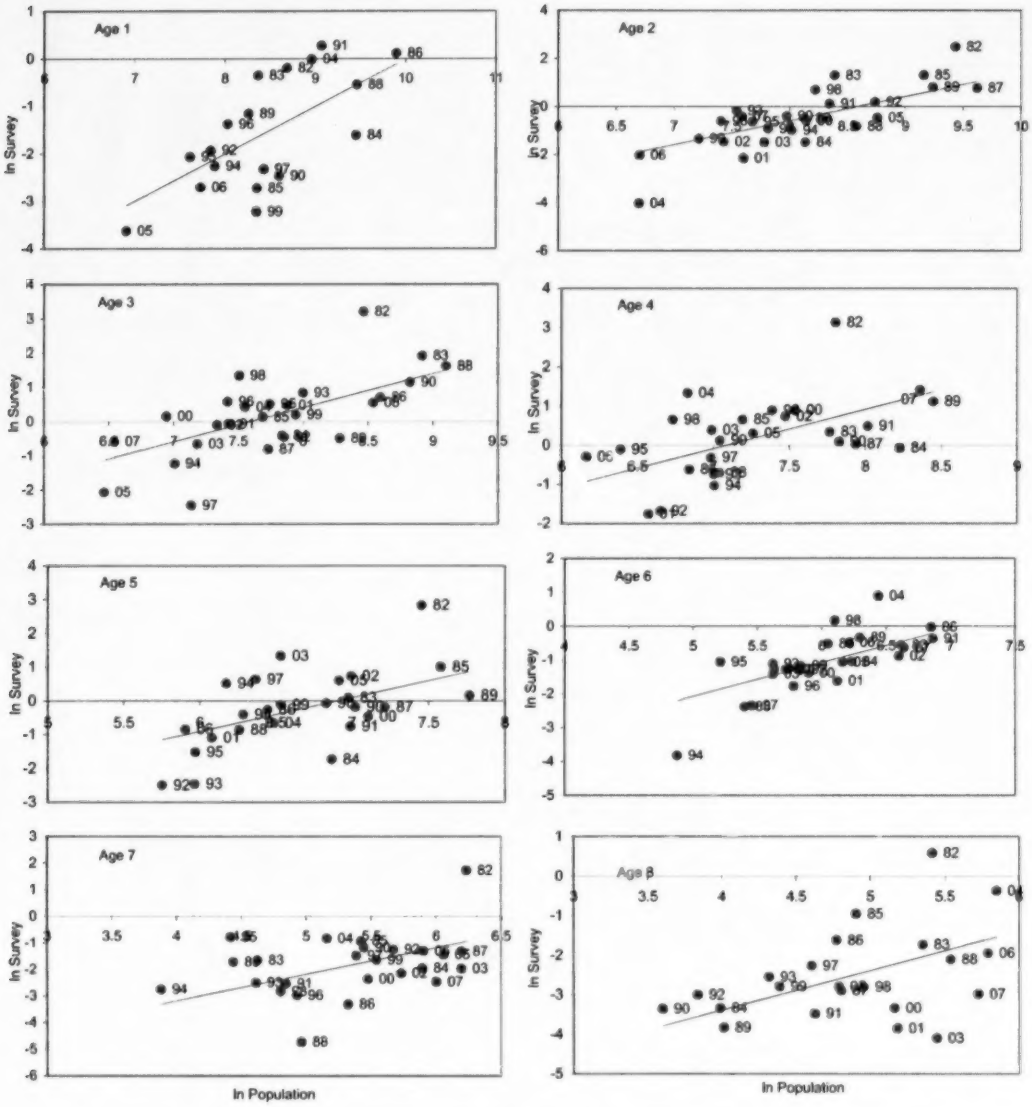

Figure 22. Observed and predicted *ln* NMFS spring Yankee 36 survey abundance versus *ln* population abundance for eastern Georges Bank cod.

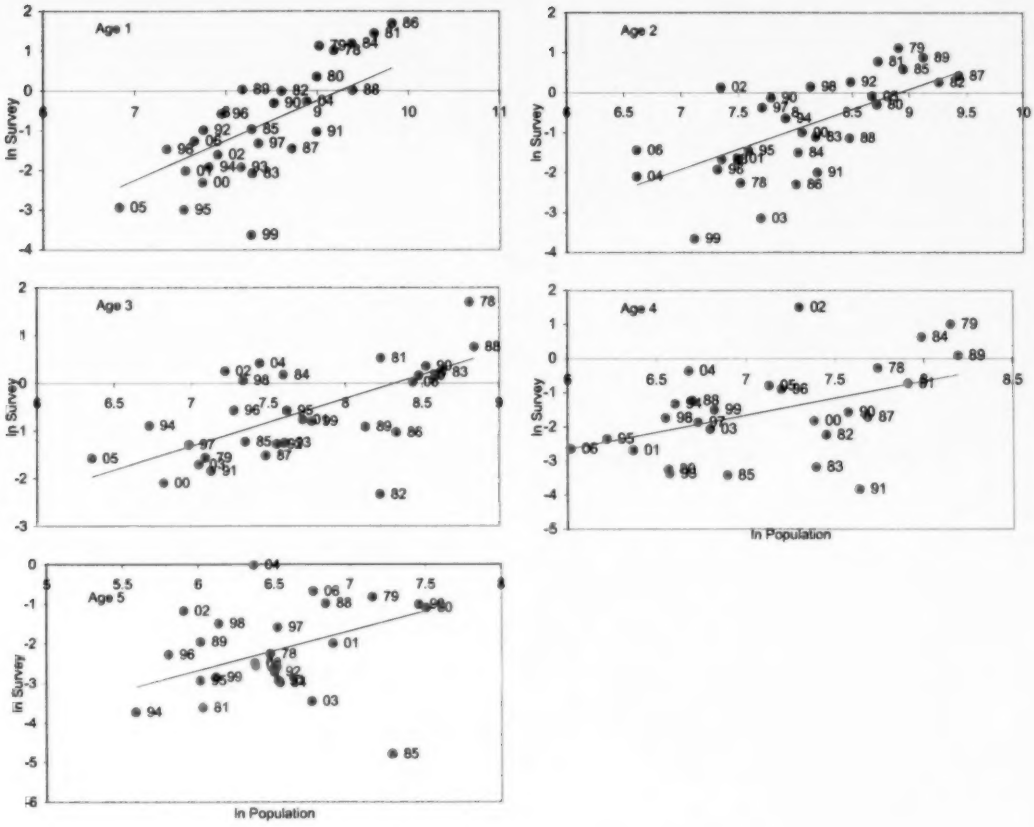

Figure 23. Observed and predicted *ln* NMFS autumn survey abundance versus *ln* population abundance for eastern Georges Bank cod.

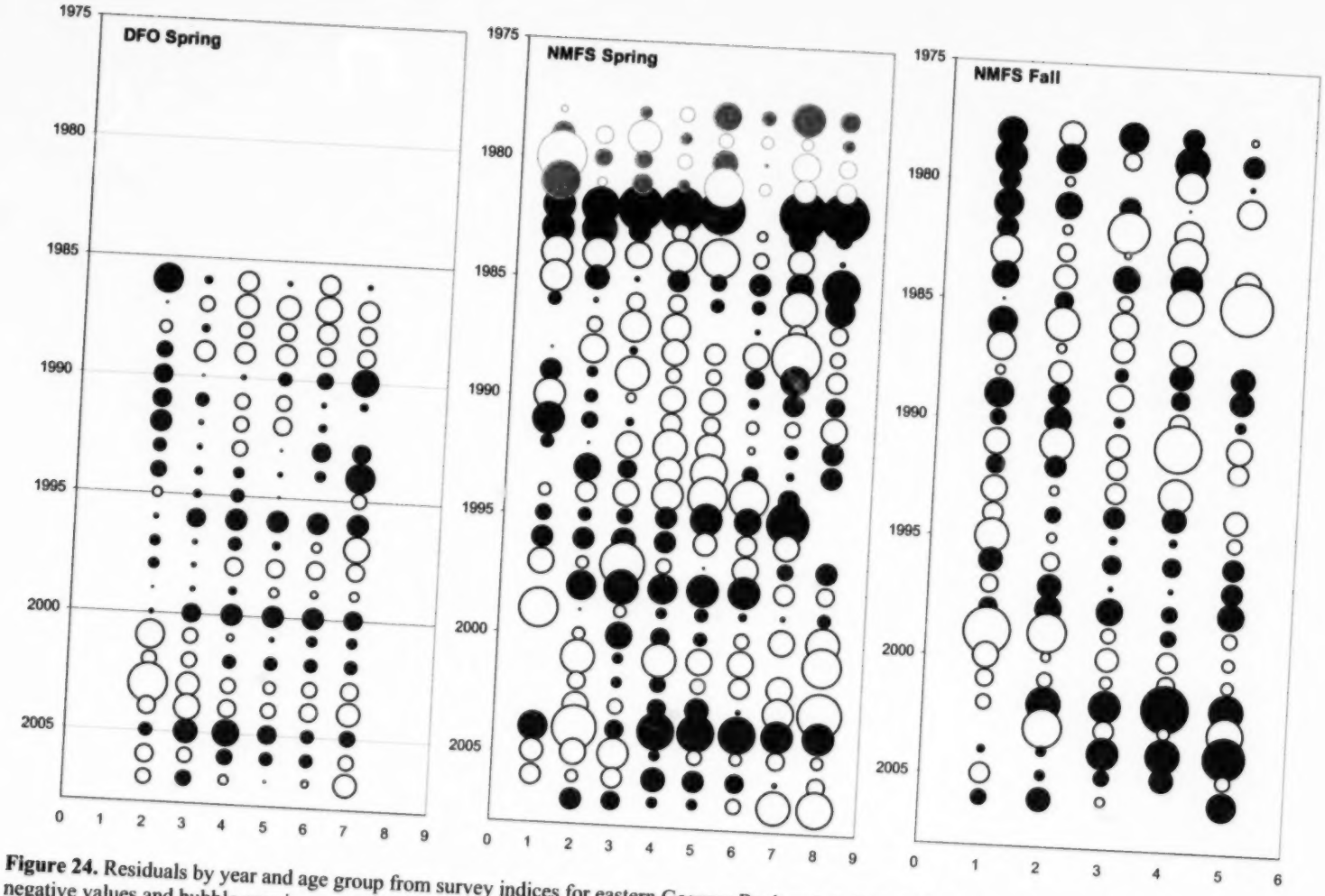

Figure 24. Residuals by year and age group from survey indices for eastern Georges Bank cod. Solid bubbles indicate positive values, open bubbles indicate negative values and bubble area is proportional to magnitude. The NMFS spring survey was conducted using a modified Yankee 41 during 1978 to 1981 (pale bubbles).

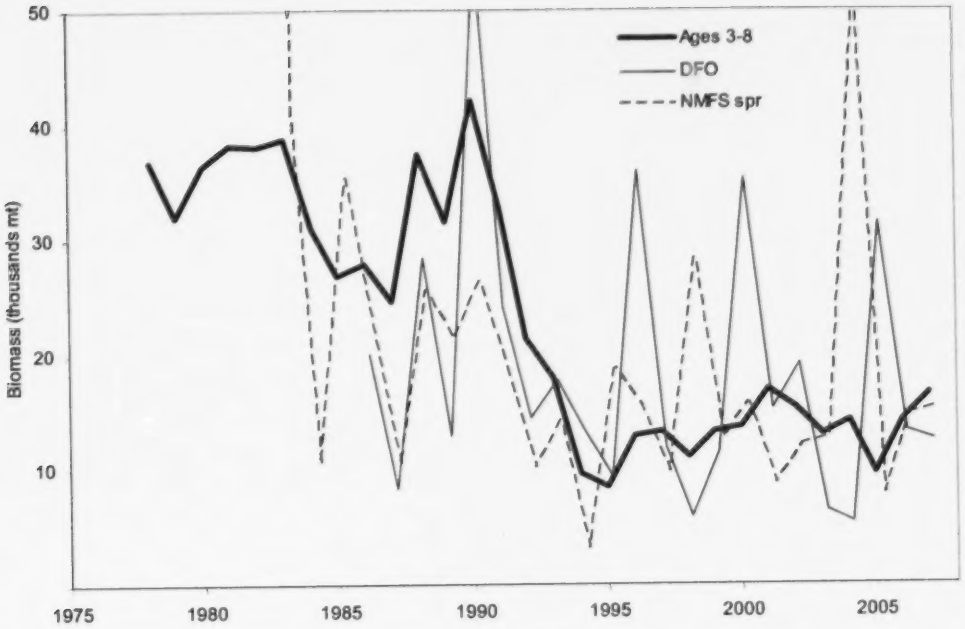

Figure 25. Overall fit of model estimated biomass for ages 3-8 to DFO and NMFS spring surveys biomass of corresponding ages for eastern Georges Bank cod.

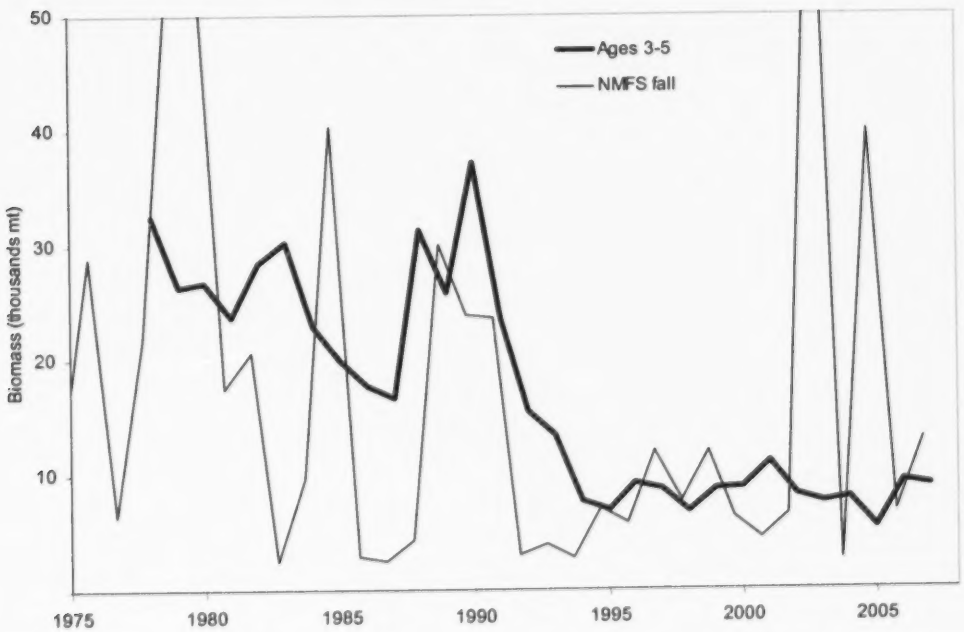

Figure 26. Overall fit of model estimated biomass for ages 3-5 to NMFS fall surveys biomass of corresponding ages for eastern Georges Bank cod.

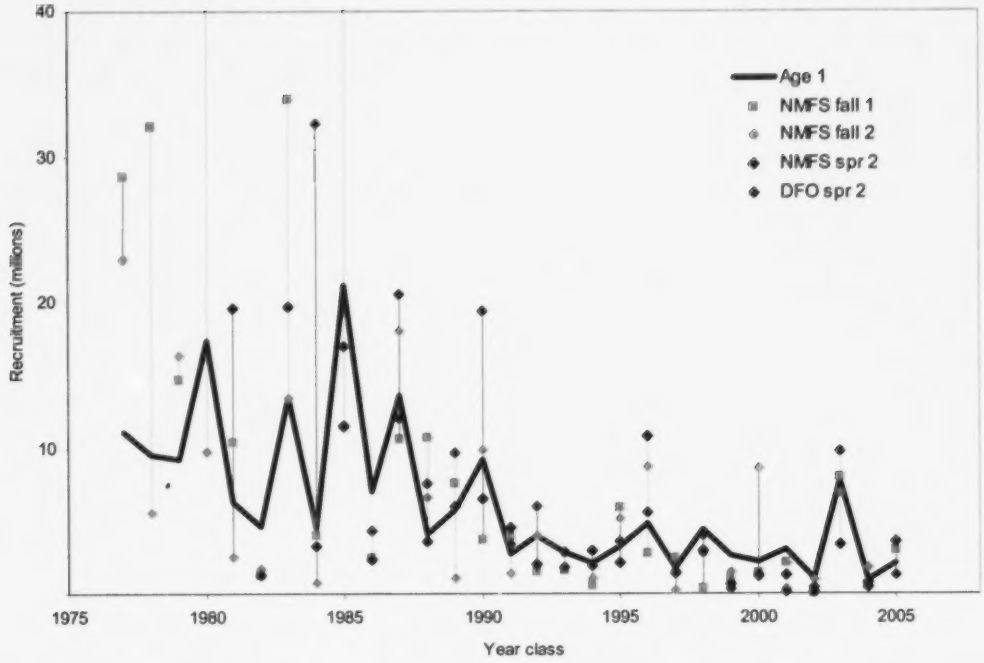

Figure 27. Overall fit of model estimated recruitment at age 1 to DFO, NMFS spring and NMFS fall surveys at ages 1 and 2 for eastern Georges Bank cod.

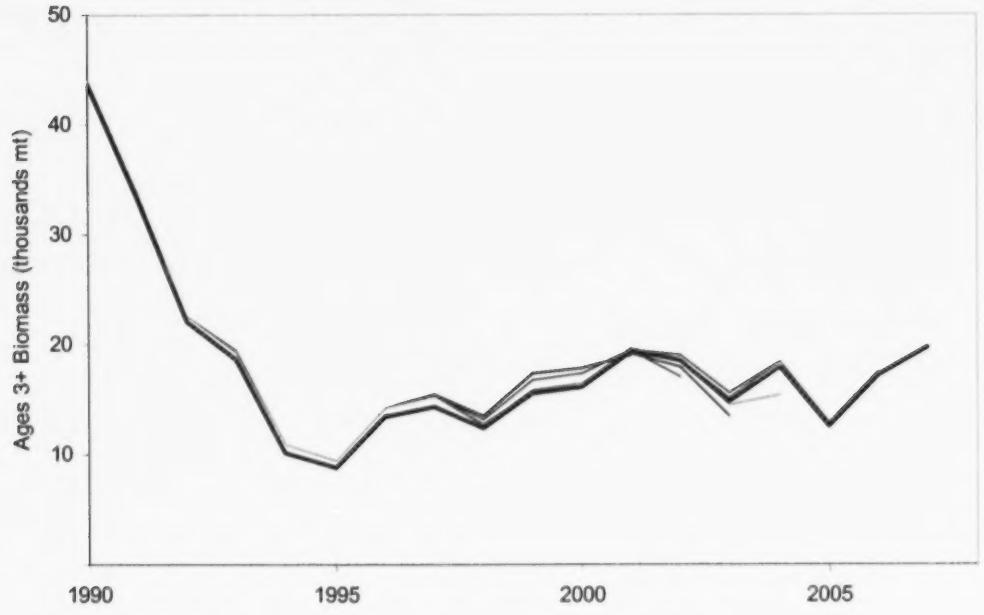

Figure 28. Retrospective pattern for ages 3+ biomass of eastern Georges Bank cod.

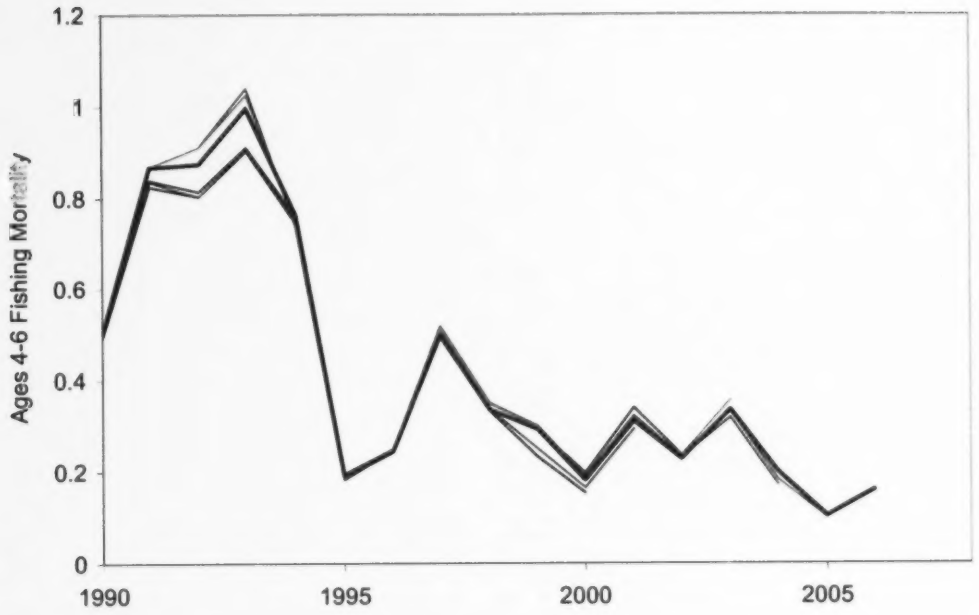

Figure 29. Retrospective pattern for ages 4-6 fishing mortality rate of eastern Georges Bank cod.

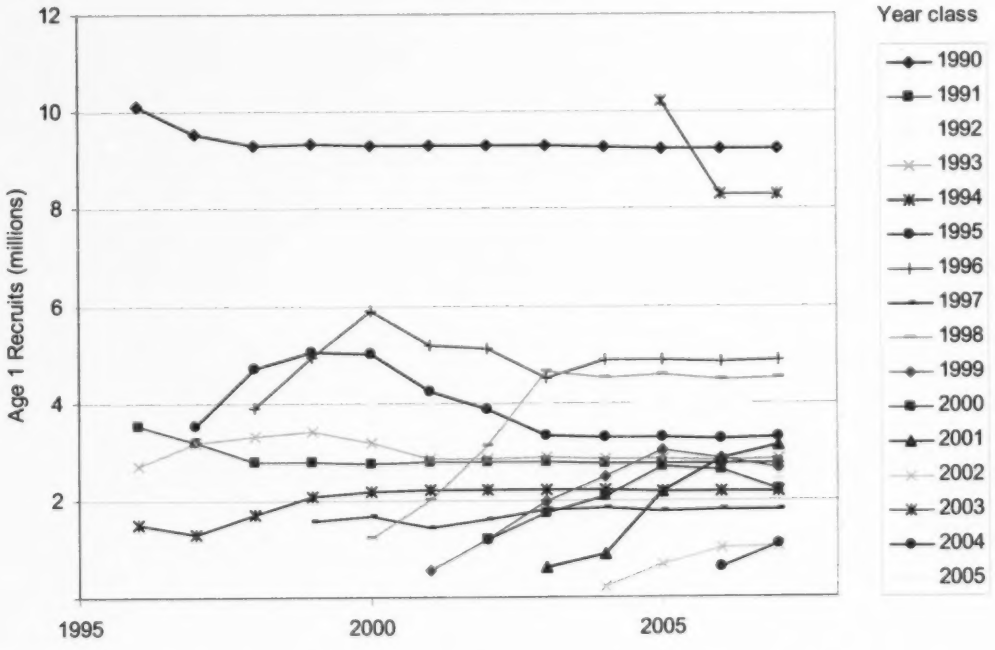

Figure 30. Retrospective pattern for age 1 recruits of eastern Georges Bank cod.

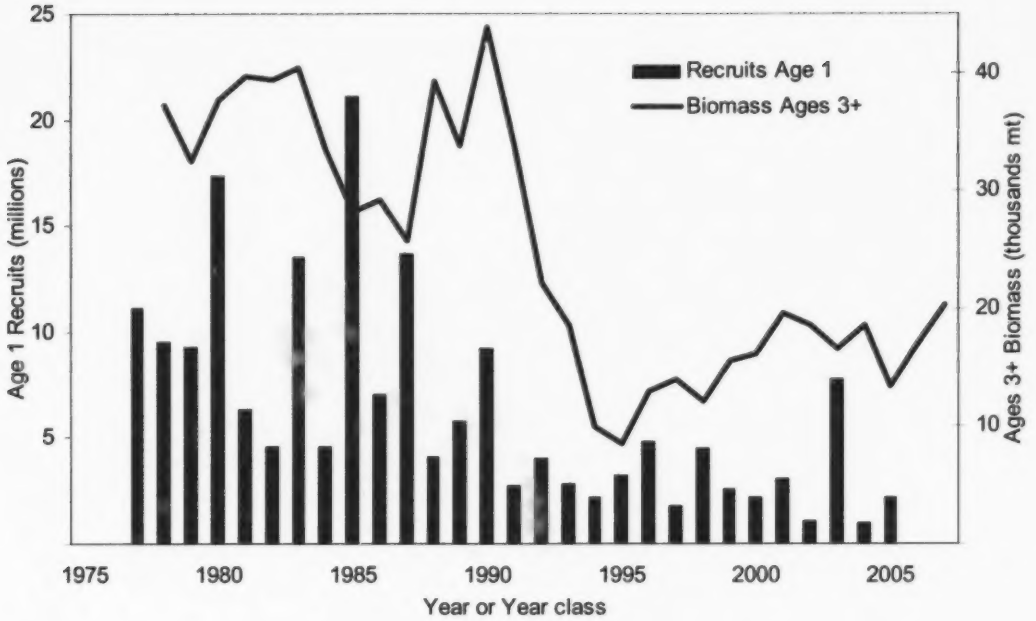

Figure 31. Adult biomass (ages 3+) and year class abundance at age 1 for eastern Georges Bank cod.

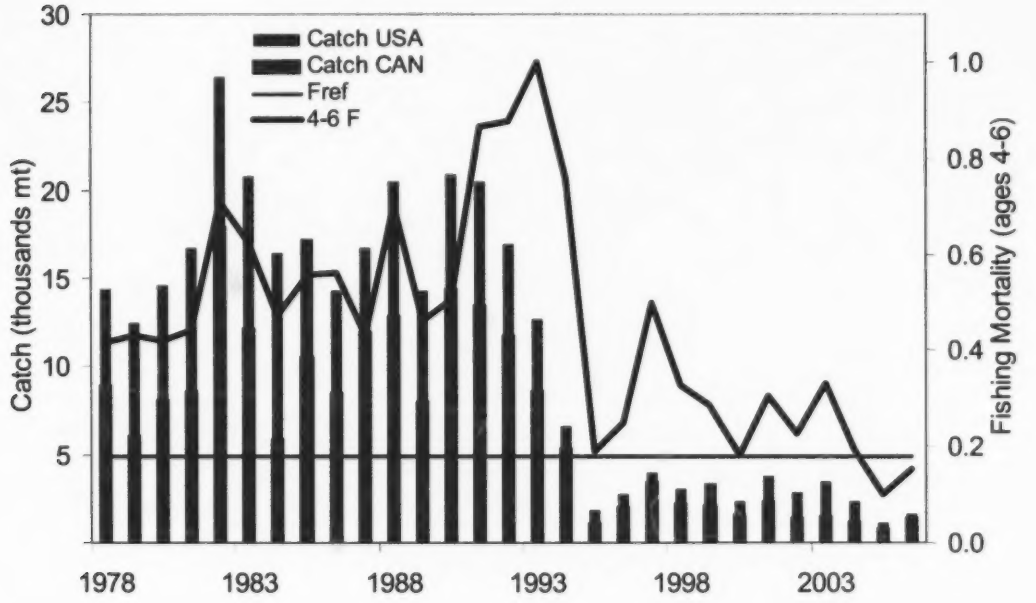

Figure 32. Fishing mortality rate at ages 4 to 6 and catches for eastern Georges Bank cod. The established fishing mortality threshold reference, F_{ref}=0.18, is indicated.

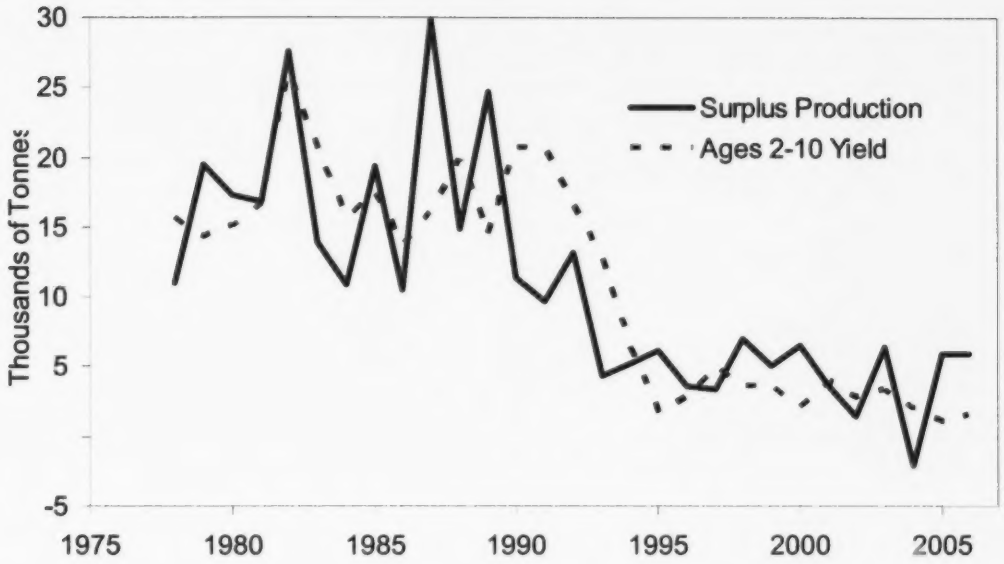

Figure 33. Surplus production of eastern Georges Bank cod compared to harvested yield.

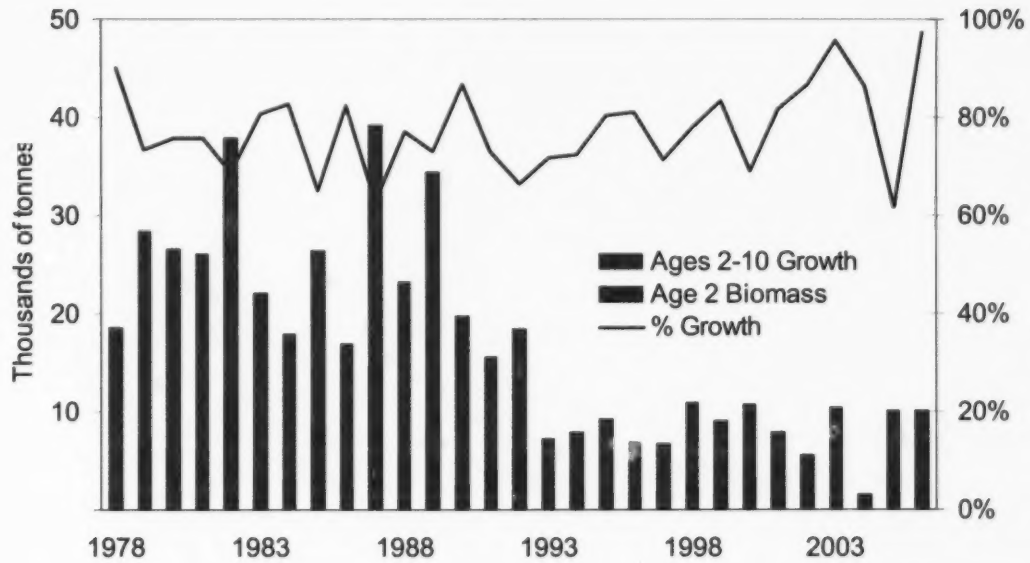

Figure 34. Components of annual production for eastern Georges Bank cod attributable to growth of ages 2 to 10 and to the amount contributed from incoming year classes at age 2.

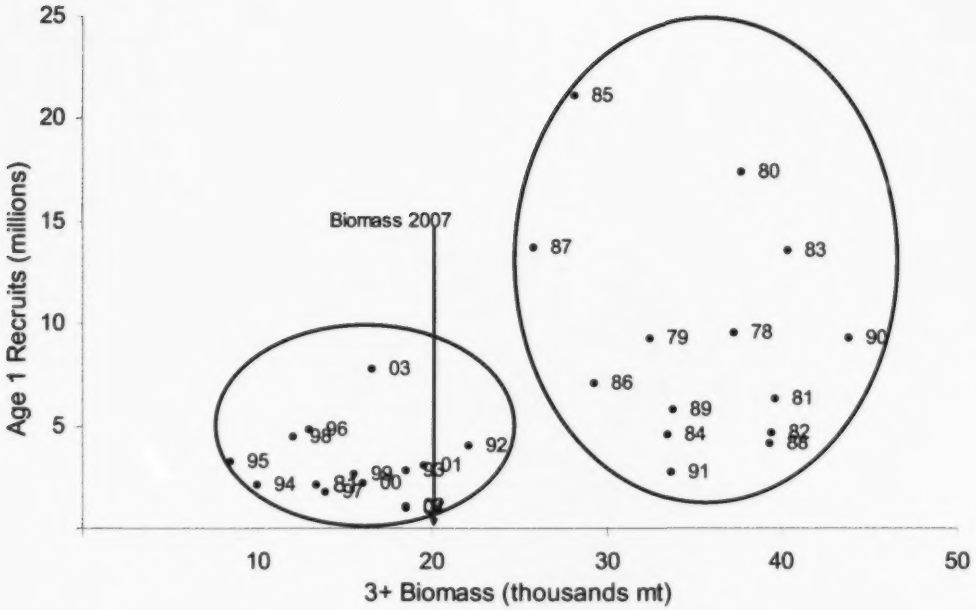

Figure 35. Relationship between adult biomass (ages 3+) and recruits at age 1 for eastern Georges Bank cod.

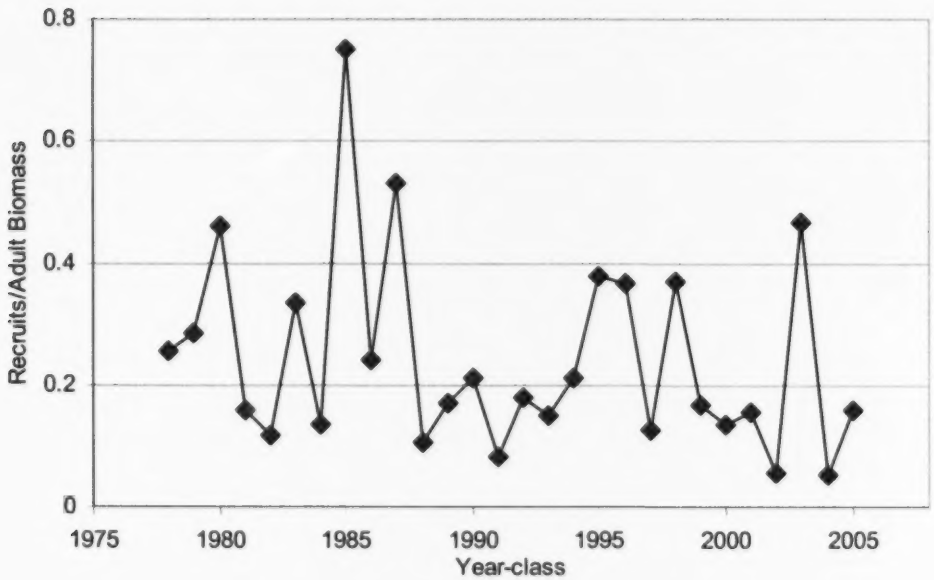

Figure 36. Ratio of recruits at age 1 to adult biomass (ages 3+) for eastern Georges Bank cod.

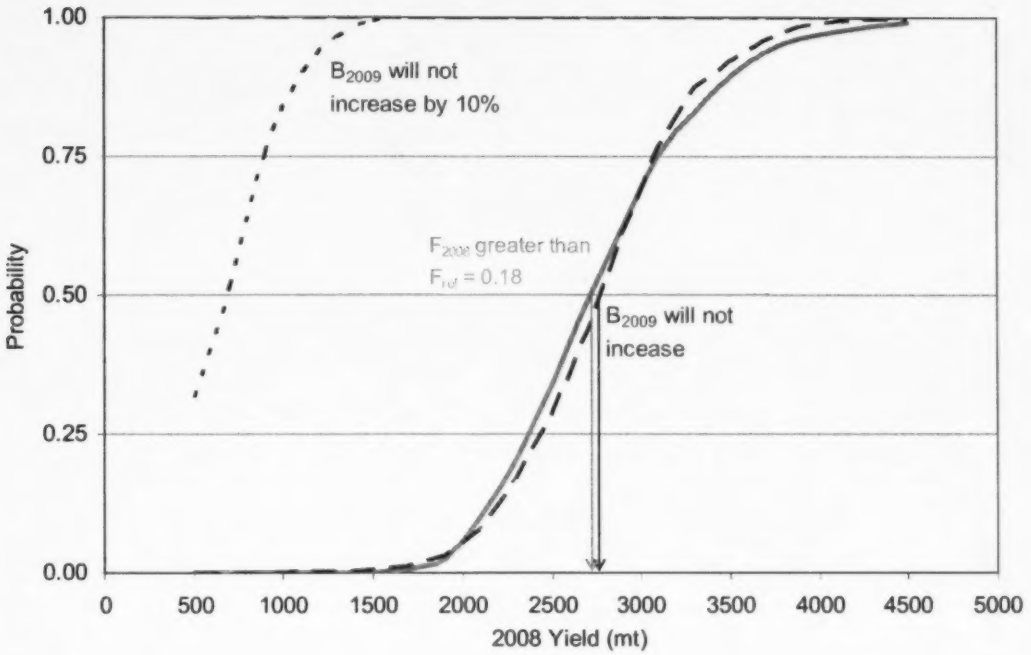

Figure 37. Risk of 2007 fishing mortality exceeding $F_{ref} = 0.18$ and risk of biomass not increasing or not increasing by 10% for alternative total yields of eastern Georges Bank cod.